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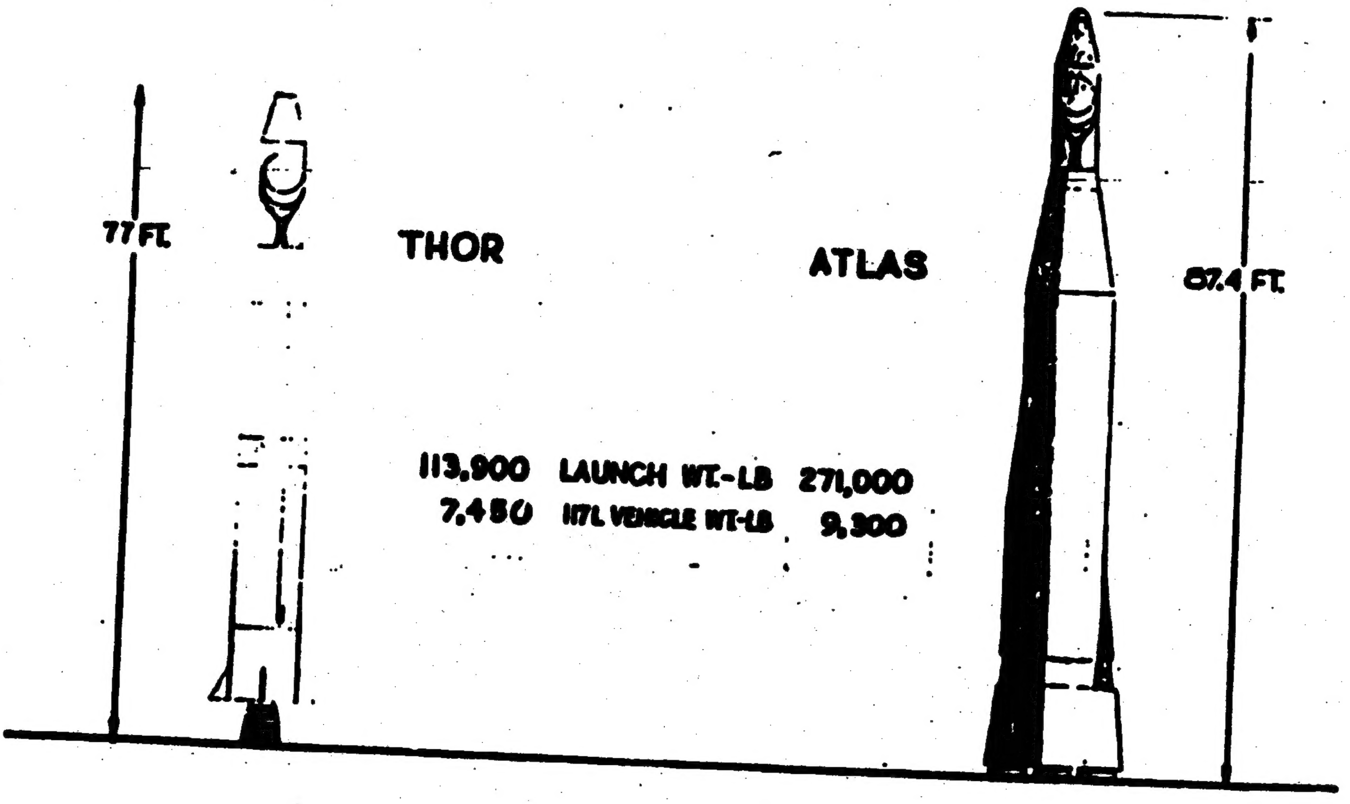
FAIRCHILD PANORAMIC CAMERA SYSTEM

WS 117L ON THOR AND ATLAS



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INTRODUCTION

The WS-117L program now under development has as its objective the provision of complete reconnaissance systems utilizing satellite borne sensing devices. The material here represents a development plan for accelerating this program, and has been prepared by the Lockheed Missile Systems Division in its role as the WS-117L Weapon System Contractor.

In the course of negotiations on 12 to 19 November 1957 for the WS-117L definitive contract, it was requested by AFBMD personnel that Lockheed consider modification of the program for a potential acceleration. Included was consideration of increasing the tempo of vehicle firings to assure greater probability of program success and to reduce the development time scale of a first Pioneer Visual flight capability by one year to March 1960. Subsequently it was requested that consideration be given to developing the Pioneer Ferret system to a time scale comparable to that of the Visual.

In view of recent emphasis on missile weapon systems, it appeared appropriate to the Contractor to consider the inclusion of two alternate approaches in the development program: (1) The use of an IRBM missile as a booster, and (2) The physical recovery of reconnaissance photographs from the orbiting vehicle. Both approaches have been a part of the Contractor's over-all program concept from its inception but had been shelved due to initial funding limitations. The combination of the two approaches will provide a system attaining very early reconnaissance capability. This is quite similar to a method proposed recently by the RAND Corporation using the Thor as a booster and a panoramic camera, in a spin-stabilized recoverable capsule, on orbit.

The overall-program presented here is essentially the same as that presented to AFBMD on 27 November and 5 December 1957, but incorporates the RAND concept for early Thor-boosted reconnaissance flights.

The Contractor believes strongly that should additional funds be available for enhancement of the U. S. military program, consideration should be given to augmentation of the present WS-117L program in the manner and amount shown in Figure 1. This would allow capitalization of the established broad WS-117L base toward expeditious accomplishment of its military objectives. Expanding the vehicle firing rate from four to 20 by Feb. 1960 will allow a more efficient utilization of the system, increase ultimate reliability, and bring about earlier reconnaissance capability.

[redacted]

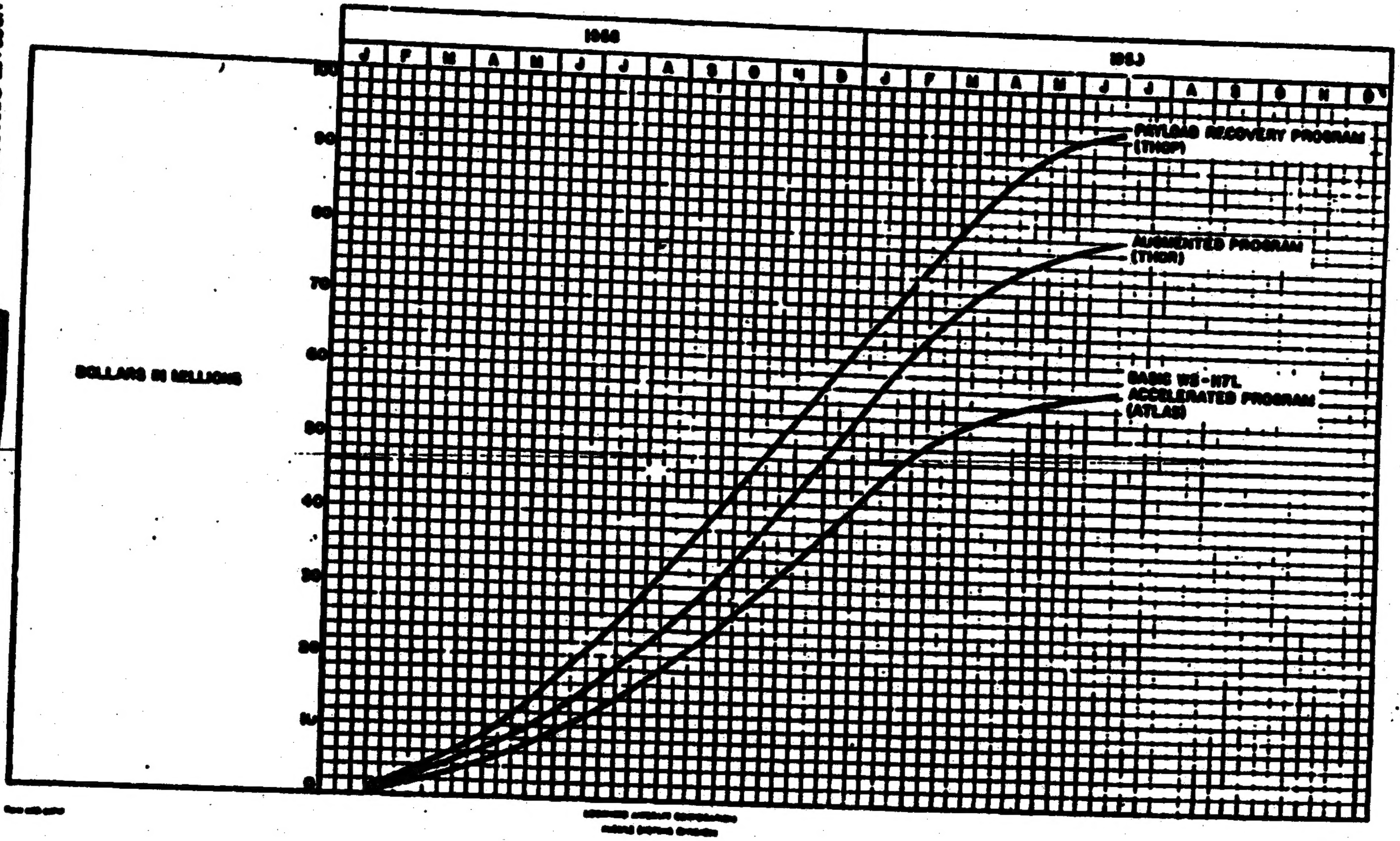


Fig. 1 WS-117L Program Cumulative Funding Requirements

[redacted]

ACCELERATION OF WS-117L PROGRAM

The acceleration of developmental effort leading to earlier WS-117L operational availability embraces the following significant additions to the program:

Advance the first firing from June 1959 to October 1958.

Advance the first Pioneer Visual, high latitude firing from March 1961 to March 1960.

[redacted]

Advance the move to IOC from March 1961 to March 1960.

Accelerate program via use of Thor IRBM as earliest available booster.

Initiate RAND-type visual-recce/physical-recovery program to advance availability of reconnaissance information with:

1 st flight January 1959

6 th flight (prototype) July 1959

Introduce use of UDMH fuel as product improvement to Hustler engine program. (Increasing Isp from 263 to 277).

Flight test (in period 1 January 1958-1 July 1959) eleven WS-117L vehicles instead of one.

Manufacture (in period 1 January 1958-1 July 1959) twenty-one WS-117L vehicles instead of original four.

SECTION I

PROGRAM SUMMARY

1.1 Development Plan

1.1.1 System Considerations

As a result of its previous WS-117L activities under the direction of AFBMD, the Lockheed Missile Systems Division is thoroughly familiar with the Air Force's requirement for developing earth satellites having the capability to perform reconnaissance of very strategic military significance. Primary categories of reconnaissance are visual, ferret and infrared-with priorities for operational requirement in that order. Long term efforts are aimed toward establishment of an Advance Reconnaissance System to become operational in the 1960-65 time period. However, efforts will also be undertaken to provide a limited reconnaissance capability as soon as possible.

The Air Force and LMSD have recently negotiated a program of effort toward these ends. The Development Plan herein presents ways and means to accelerate the existing program through increased effort and materiel-augmentation with the eventual result of earlier operational capability and increased overall effectiveness.

The program is planned to proceed from the simple to the more complex, with each point of capability embodying the best compromise between scientific state-of-the-art and early availability of Reconnaissance Weapon Systems for military use. To enhance this effort, the basic program would be supplemented by the development of an alternative Photographic Payload which can be physically recovered from a vehicle on orbit. In this case, the WS-117L vehicle would be boosted to orbit by a Thor Booster and would carry a recoverable visual payload similar to that described in recent Rand Corporation literature.

LMSD's overall activities are organized in the following phases:

1.1.1.2 Program I.

The objective of this program is the achievement of orbital capability on an accelerated time scale. The program calls for the design and development of a basic WS-117L vehicle utilizing a liquid-fueled orbit-boost engine and providing capability for carriage of various payloads. Vehicle design is based on a gross weight, with fuel and payload of 9300 pounds that allows the off-loading of fuel or payload for satisfaction of special flight objectives. Final Program I flight for demonstration of orbit capability is established for February 1960. The achievement of a reliable capability on an accelerated time scale requires the initiation of orbit flights by October 1958. The first four of these flights will utilize the Thor IRBM because of their early availability. The succeeding ten flights will be boosted by the Atlas ICBM in accordance with existing plans. All flights will be orbit-tries. Concurrently with the achievement of an orbital capability, a considerable effort will be spent during Program I in obtaining initial orbital testing of visual, ferret and infra-red reconnaissance payload components, partial subsystems and later, complete subsystems. These tests will provide the extremely important developmental phase of orbital environmental test conditions and will contribute to the acceleration of an early reconnaissance capability in later programs.

1.1.1.3 Program II.

The objective of this program is the achievement of pioneer visual reconnaissance capability which includes mapping physiographic features at a ground resolution at one hundred feet and a locational accuracy of one mile. Objectives of such reconnaissance are airfields, industry complexes and sea coast installations detectable at this scale. While Program II is not covered in detail in this Development Plan, it should be noted that the first Pioneer Visual Reconnaissance flight will be launched from I.O.C. in March 1960 as specifically directed by AFBMD.

Program II-A. The objective of this program is the early achievement of a Visual Reconnaissance capability through utilization of other techniques and sources than those incorporated in existing basic WS-117L Weapon System Program. This is done via utilization of panoramic camera techniques currently available from aerial reconnaissance state-of-the-art. A requisite part of this program is the utilization of recovery of the Visual Payload from the orbiting vehicle by utilizing techniques described by the Rand Corporation. In this program, basic WS-117L vehicles, each loaded to approximately 7200 pounds, would be boosted by a Thor IRBMs to orbit about 135 statute miles above the earth. Following acquisition of reconnaissance data, and at an appropriate point in its orbit, a command signal would initiate recovery of the Payload through utilization of retroactive rockets. The descending capsule would be recovered from a pre-selected point in the Pacific Ocean, North of Hawaii. Data thus collected would have approximately the same characteristics of resolution as that prescribed for Program II above. It envisioned that the objectives of this program could be satisfied by six firings the first of which would be performed in January 1959 and the last in July 1959.

1.1.1.4 [redacted]

1.1.1.5 Advanced Development Programs

Later development programs will be carried out in order to provide an advanced reconnaissance capability. Program IV, the Advanced Visual Program, will provide greatly increased ground resolution (20 ft.) with a locational accuracy of one half mile. The system may incorporate features to allow the programming of the camera to point to areas of specific interest. [redacted]

Programs VI and VIII represent the development of continuous satellite surveillance systems utilizing advanced visual [redacted] systems.

1.1.1.6 Program VII

The Infrared Surveillance Program has as an ultimate objective, a system of satellites on ortit, placing unfriendly territory under continuous and complete surveillance. Initially the early system will be capable of detecting ICBM launchings and transmitting an immediate warning of an imminent attack.

1.1.2 Subsystem Considerations

1.1.2.1 Airframe Subsystem

The airframe Subsystem consists of the structure, propulsion tankage, outer skin, installation supports and certain mechanical and electrical equipments. The major portion of the development effort on this subsystem will be conducted at LMSD including design, fabrication, assembly, and ground support equipment development. LMSD will rely heavily upon outside purchase for small components.

1.1.2.2 Propulsion Subsystem

The Propulsion Subsystem consists of the main orbital thrust rocket engine with the associate propellant feed system and control mechanisms, the thrust producting system for vehicle attitude and roll control, the auxiliary rockets for ullage control together with all necessary ground based support equipment used for the testing, calibrating, checkout and servicing of the subsystem. All research, development and fabrication of the orbital thrust rocket engine will be performed by Bell Aircraft Corporation. LMSD will perform the over-all subsystem development activities.

1.1.2.3 Auxiliary Power Subsystem

The APU Subsystem consists of the electrical power system for the complete satellite system together with the necessary ground support equipment. The subsystem design and development is being conducted by LMSD with appropriate subcontracting for specific battery and other subsystem developments.

1.1.2.4 Guidance and Control Subsystem

The Guidance and Control Subsystem consists of equipments required to fulfill functions associated with the initial boost, coast, orbiatl boost, reorientation, and orbital stabilization. LMSD is directing the over-all development of the necessary equipments required. Major components such as the inertial reference package and the horizon scanner will be developed by appropriate subcontractors. Both component and complete subsystem tests will be conducted by LMSD.

1.1.2.5 Visual Reconnaissance Subsystem

The Visual Reconnaissance Subsystem consists of the satellite-borne equipment required to collect, process, and store visual pictures and later to convert these pictures into video form for transmission to the ground with equipment which is a part of the Ground-Space Communications Subsystem. This subsystem also includes the necessary ground data-processing equipment. LMSD is planning and directing the development program with the major hardware development and fabrication of subsystem equipment being subcontracted to Eastman Kodak Company.

1.1.2.6 Electronic Reconnaissance Subsystem

[redacted]

1.1.2.7 Infrared Surveillance Subsystem

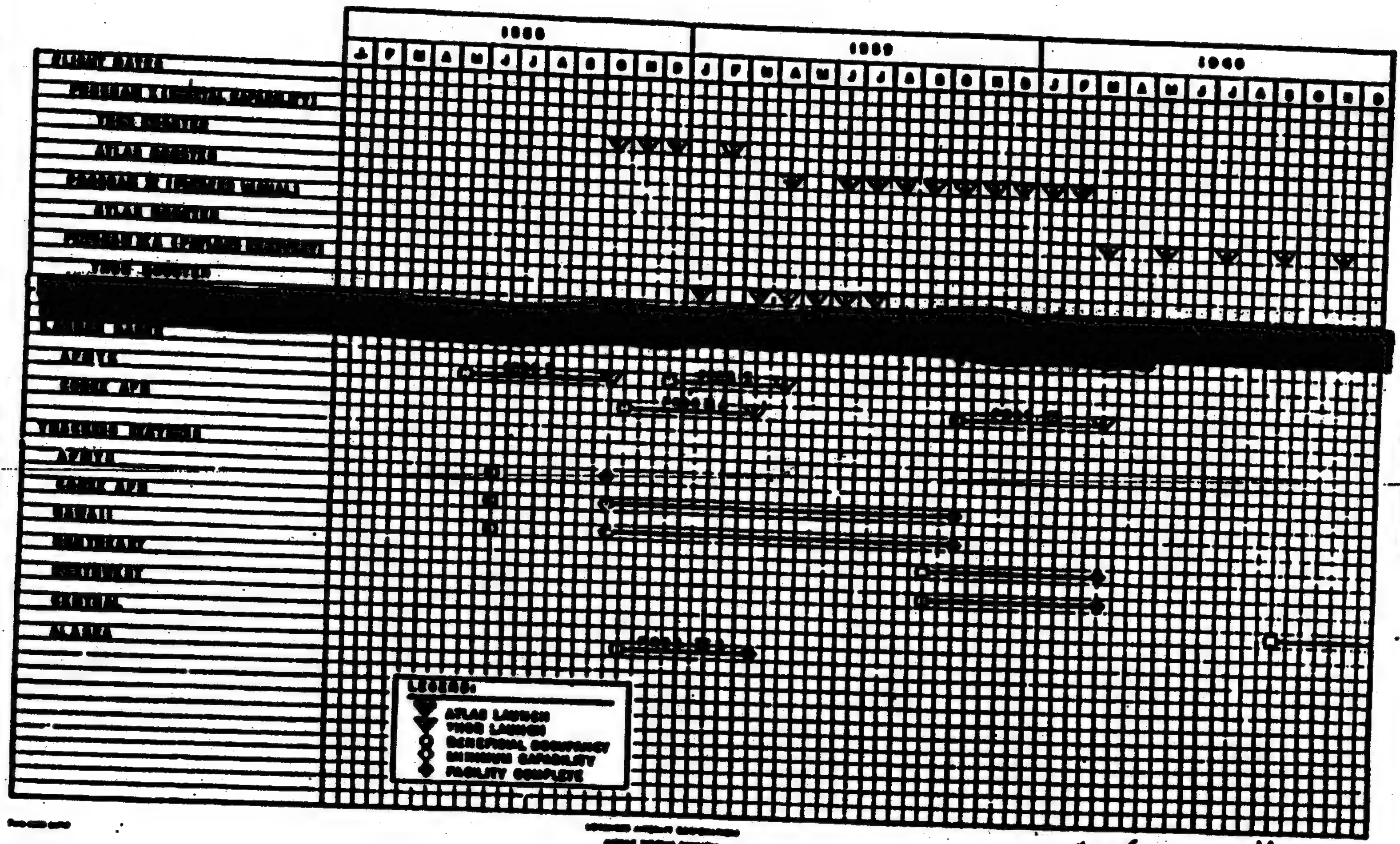
The Infrared Surveillance Subsystem consists of equipments for collecting infrared data from enemy ICBM's, and high-altitude jet aircraft and transmitting this data back to appropriate ground stations in order to provide warning of impending attack and surveillance of air traffic patterns. The over-all subsystem program is being directed by LMSD. Major subcontracts are underway for various phases of study and design work on components and subsystem equipment.

1.1.2.8 Ground-Space Communications Subsystem

The Ground-Space Communications Subsystem consists of equipments to perform the following functions: Acquisition and Tracking; Telemetry; Reconnaissance Data Link; Vehicle Antenna Systems; Ground Station Communications; Computers, Timers, and Command System. LMSD will direct the over-all design, development and test of these equipments. The Philco Corporation as the major subcontractor will have the responsibility for the development of the integrated subsystem together with specific developments as required.

1.1.2.9 System Management

The acceleration of this program will require the application of unusual measures in many cases to assure that an effective Weapon System is developed in the short time available. In the area of testing and operations, extensive captive testing of both subsystems and completely assembled flight systems will be necessary. Since it might not be possible to system-test each vehicle prior to flight, the test of one (1) complete vehicle out of selected production runs will satisfy necessarily reduced test requirements. In the manufacturing area, it will be necessary to stream-line procedures for drawing release, specification compliance, pilot line production, material procurement and other associated problems. Plans are now being laid to bring about these desirable end results. The acquisition and training of manpower presents a particularly imposing problem because of the unusual skills required and the heavy security requirements imposed. The immediate implementation of a program for acquisition of new personnel must be undertaken. Ground Support equipment for this program, as well as associated facilities, will be developed under an integrating plan by LMSD, although, extensive outside purchase of equipment is contemplated. Both the acceleration of the program and its enhancement of reliability will be accomplished by strong augmentation of testing for checkout and like equipments.



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Mn 60

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Summary Schedule - WS-117L Accelerated Program

1.2 Technical Feasibility

Technical feasibility analyses performed in conjunction with the program acceleration comprise two parts: the use of the Thor missile as a satellite booster and the use of physical recovery for early photographic reconnaissance data (essentially the system proposed in RAND Report No. RM 2012).

It is planned to use the Thor booster in two ways: to augment the flight proving program of the WS-117L vehicle (Program I) and to place the RAND-type recoverable camera capsule on orbit. It was found that the Thor booster will place the present WS-117L vehicle on a 300 statute mile orbit allowing approximately 100 pounds for instrumentation when fired from AFMTC. The concept of using relatively simpler IRBM class missiles to supplement ICBM class boosters in the flight-proving program is not a new one. The contractor presented this in the First Quarterly Pied Piper Report of October 1955.

In considering the best way of placing the Rand type payload on orbit, it was found that the WS-117L vehicle was equal in performance to the method assumed by Rand (Thor plus Vanguard second and a small third stage. In fact, the WS-117L vehicle in combination with the Thor is the optimum vehicle that can be added to the Thor to provide a two stage satellite. The reason for this is because of the high performance inherent in the WS-117L application and because the WS-117L vehicle is restricted in size for the Atlas application due to load carrying limitations of the latter's balloon-type construction. Figure 1-1 illustrates this point.

Figure 1-2 presents performance envelopes of two and three-stage satellites using the Thor missile as the first stage. It is assumed that the stage (stages) placed on the Thor represent the best presently available liquid rocket performance and structural design efficiency.

Figure 1-2 shows the relative performance of the Vanguard second-stage and the WS-117L vehicle when placed on the Thor. Here it

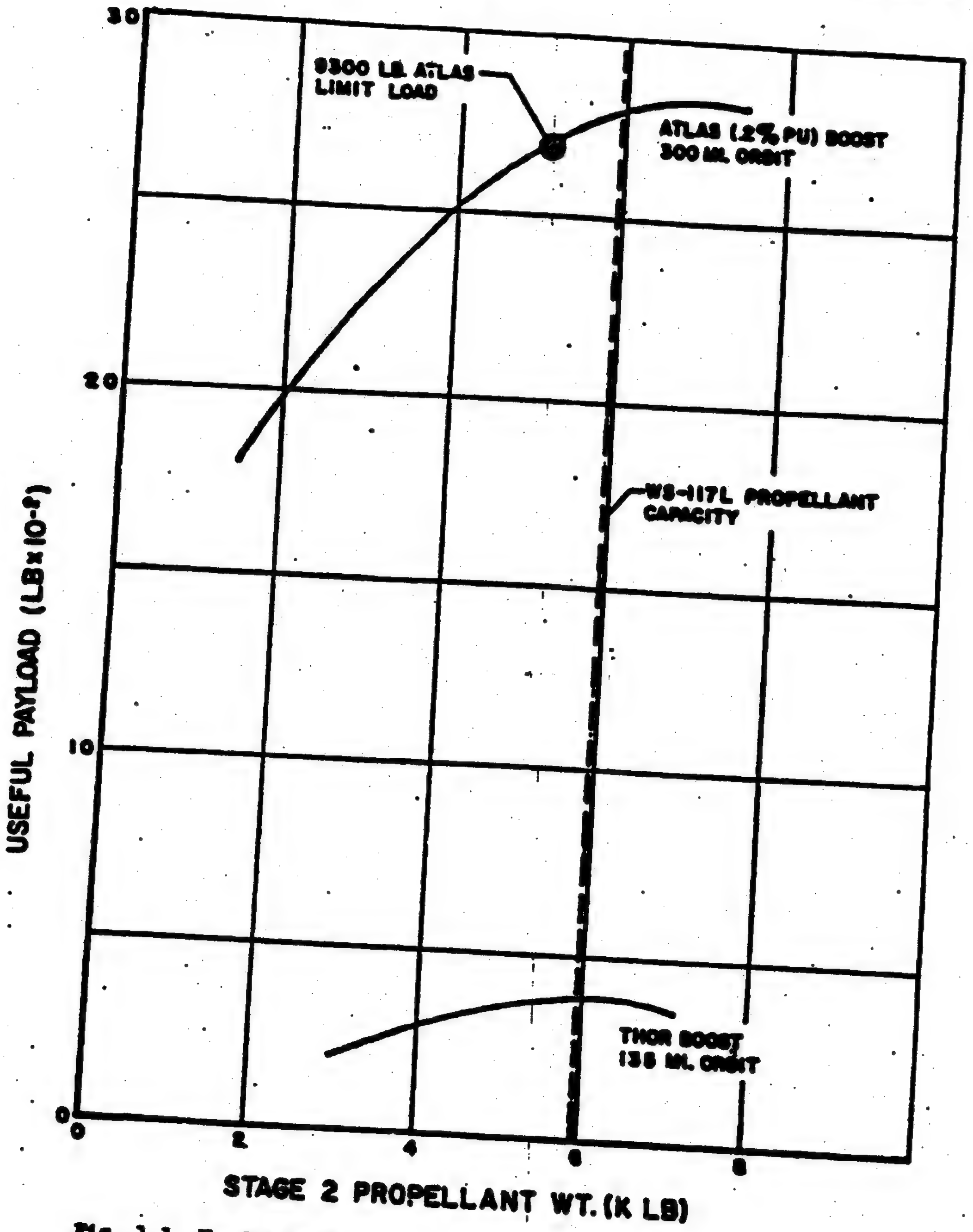

Fig.-1-1 Useful Payload vs Propellant wt. WS-117L Vehicle - Polar Orbit

[redacted]

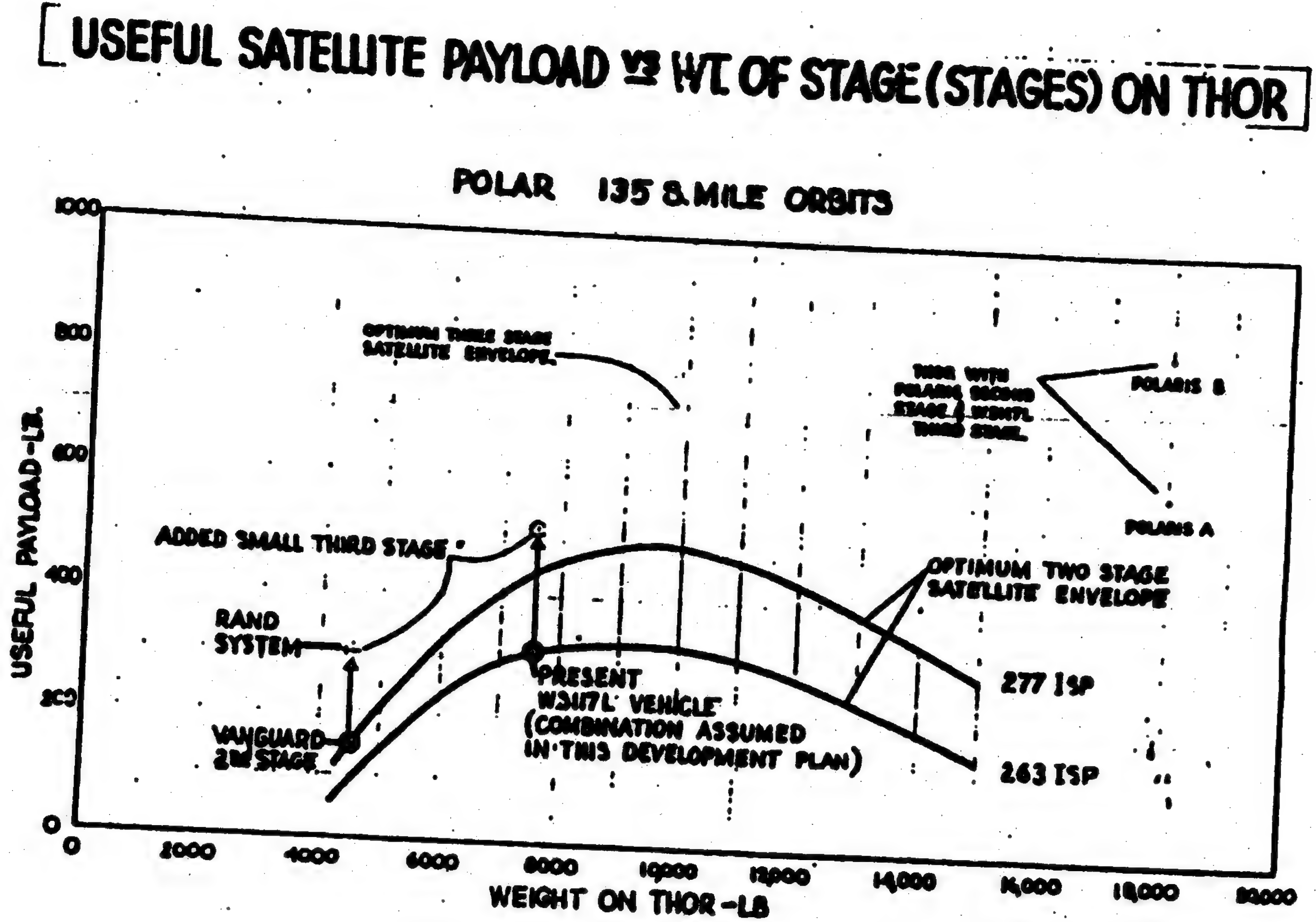

Fig. 1-2

[redacted]

is indicated that the WS-117L has a higher payload capability than the Vanguard because the WS-117L is the proper size despite the higher specific impulse of the Vanguard engine*.

In order to launch a satellite, the last stage must operate at orbit altitude. This means that a two-stage satellite must be launched on a less than favorable flight path from a performance point of view. If a small third stage is added it allows the second stage to be operated at lower altitudes and at a higher trajectory efficiency. Thus, although this small third stage does not contribute significantly toward the total impulse, it does allow considerably greater payloads. This point is illustrated in Figure 1-2.

RAND has assumed such a scheme in order to get enough payload capability to place their reconnaissance capsule on a useful orbit using the Vanguard second stage. Use of the small third stage versus a two-stage satellite is disadvantageous for reliability reasons and also because the last stage is not fired until the vehicle has coasted to apogee, which in the case of a three-stage vehicle is several thousand miles down range. For example, the RAND-assumed vehicle does not go on orbit until it is nearly in the Antarctic region. This introduces considerable difficulty in monitoring any functions while establishing the orbit. Furthermore, unless a guidance system is included in the last stage, great uncertainty is introduced in the type of orbit that is established.

On the other hand, the WS-117L vehicle will go on orbit within 900 miles of the launch point and this is considered to be quite significant for both guidance and instrumentation.

In the Teller Committee report, it was stated that the "WS-117L vehicle on a Thor would yield 200 to 400 pounds on orbit as proposed by Lockheed." Indeed, the material presented by Lockheed was based on the conditions that the payload would be placed accurately in an orbit with the latter useful for reconnaissance purposes (i.e., polar). The Contractor's

*The Vanguard engine does not have a pump and relies on tank pressures of 300 psi. At sizes commensurate with the WS-117L application, unfavorable Vanguard tank weights would offset the specific impulse advantage and would yield comparable performance only to the WS-117L engine.

performance figures were based on detailed designs, on rigorously optimized trajectories utilizing the 1103A computer, and on a large amount of system design data of satellite-type vehicles as a result of the WS-117L program over the last three years.

The Contractor has not been able to show on this same basis useful payloads of "400 to 800 pounds" for the Vanguard second and third stages as proposed by Douglas in the Teller report, or the large payload numbers presently being quoted by Ramo-Wooldridge. Part of this difference could be accounted for if the latter studies assume launching eastwardly from AFMTC. Under these circumstances the WS-117L vehicle would enjoy a similar increase in payload capability, but such an orbit is not useful for reconnaissance purposes. The remaining difference might be accounted for by more optimistic performance assumed for the Thor missile than is indicated by present WS-315A data available to Lockheed. Lockheed personnel have not been granted authorization by AFBMD to discuss in detail improved Thor performance with Douglas. If such improvements are in the offing it would be highly desirable to consider same in context with future applications of Thor to the WS-117L program.

The two-stage combination proposed by the Contractor is adequate to provide a useful reconnaissance mission in the time period prior to the WS-117L/Atlas reconnaissance systems. For this reason, the Contractor does not recommend for this early application the additional complexity of either a three-stage satellite or the development of higher performance propulsion systems. Higher performance systems will pay for themselves in the WS-117L program in the early Atlas boosted vehicles as well as in later applications of the Thor missile. For this reason, the Contractor is presently proposing to intensify the effort under the advanced WS-117L propulsion system that is already a part of the WS-117L development program. It is planned to sponsor development of a modified Hustler engine (providing 277 specific impulse) and the development of a high performance engine of 340 to 440 seconds specific impulse, using fluorine as the oxidizer. The utility of higher performance engines in the follow-on Thor reconnaissance systems is discussed later in this Summary Section.

[redacted]

The early Recoverable Reconnaissance System is based upon the concept of the physical recovery of high resolution photographs of enemy territory taken from a satellite orbit. Complete coverage of the USSR North of 45 degrees latitude is accomplished by a satellite orbiting at an altitude of 135 statute miles and scanning 45 degrees each side of vertical during a four-day period.

The method for the mechanization of this concept makes use of the dynamics of a rotating body to maintain proper orientation in inertial space as well as using the spin of the body to operate a transverse panoramic camera. This method results in a relatively lightweight reconnaissance package which is quite compatible with the performance of the Thor/117L System as previously discussed.

Figure 1-3 shows the general reconnaissance scheme and Figure 1-4 shows the sequence of events for a mission. It can be seen that immediately after establishment of orbit the vehicle and camera package are oriented for proper photography over the zone of interest. After attitude orientation the camera package is caused to spin at approximately 18 RPM and is then separated from the vehicle. This rotation is sufficient for stabilization purposes. At this rotation rate, camera operation on every third revolution over the zone of interest provides continuous coverage. Proper timing of the camera operation is obtained by combining joint operation of a timer and sun sensor.

After a sufficient number of passes have been made by a vehicle, the reentry and recovery phase of the mission is initiated as the package passes near the Zenith over a selected tracking station in Alaska. A signal is initiated which will cause a solid propellant rocket in the package to modify the orbit so that the package re-enters the earth's atmosphere. During passage through the atmosphere the vehicle slows to subsonic velocity. A heat shield on the forward end of the package, accomplished by use of a material ablation technique, will protect the reentry body and internal components from the intense heating

RECOVERY MISSIONS

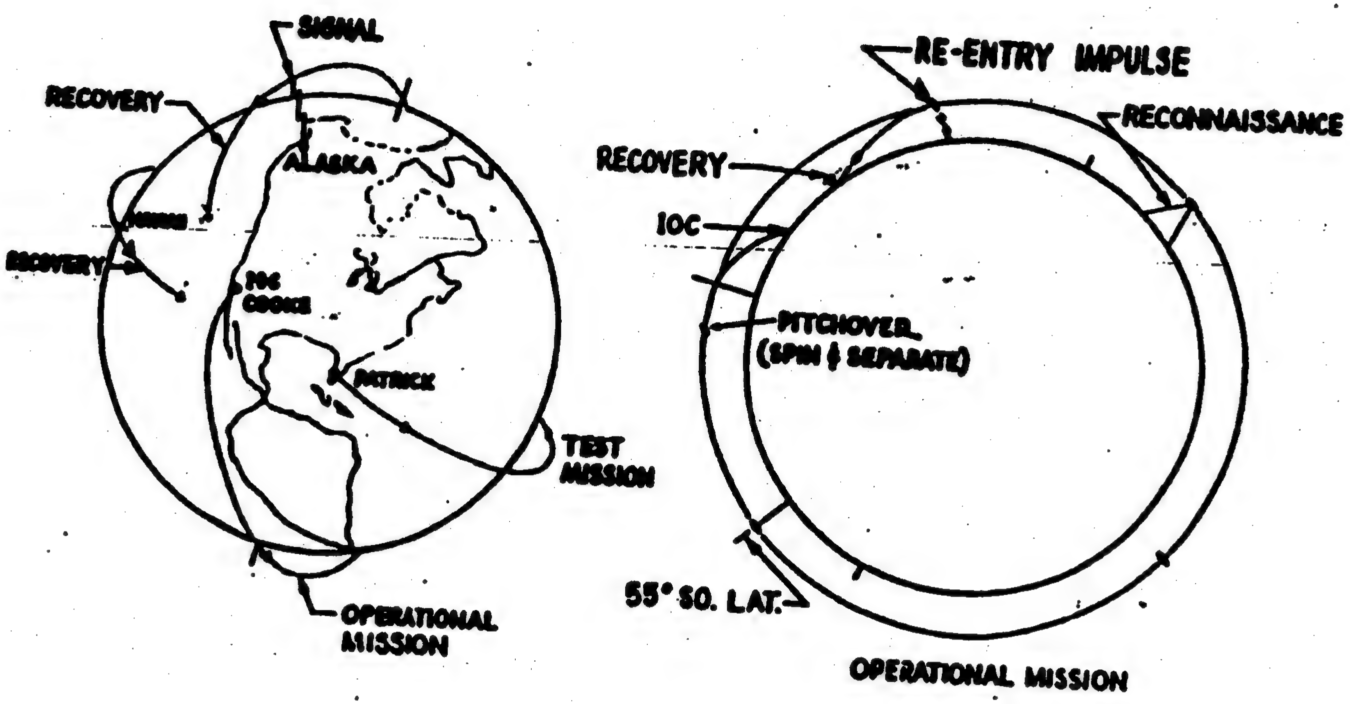

Fig. 1-3

[redacted]

LAUNCHING TRAJECTORY

POLAR ORBIT

GUIDANCE

- AC FOR THOR
- INTERIM GUIDANCE FOR WS117L

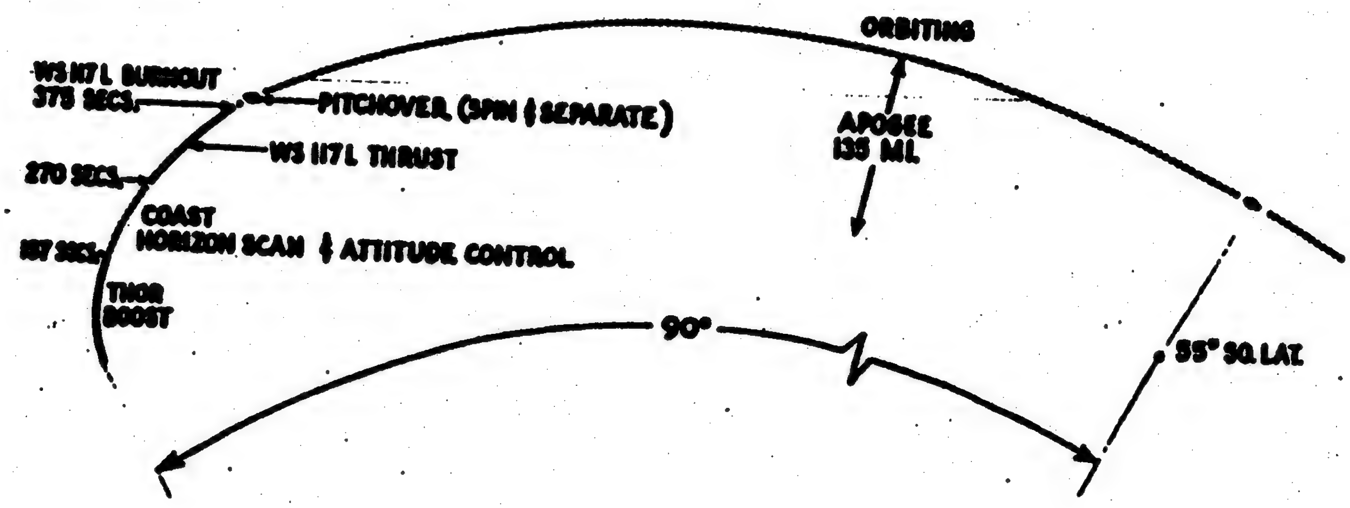

Fig. 1-4

[redacted]

encountered as the vehicle reenters the earth's atmosphere. The distance from initiation of the rocket to the impact in the ocean off the West Coast of the U. S. will be about 1500 miles. The CPE of the impact will be approximately 30 miles. Air and/or Naval surface craft will be utilized in recovery aided by radio beacon, SOFAR, and/or sea dye marker signals.

The Recoverable Reconnaissance System selected here is quite similar to the one proposed by RAND (RAND Report RM 2012), but differs in two ways.

First, since the entire WS-117L vehicle goes on orbit before ejection of the capsule, the latter is simply spun up and separated. Second, only the camera and film, and the recovery components are contained within the recovery body which reduces the mass reentering the atmosphere and also gives an improved stability through better center-of-gravity location. Analysis by the Contractor yielded over 100 pounds of ablation material needed for the RAND recovery weight (compared to 60 pounds computed by RAND). By reducing the weight of the system being recovered, retention of the 60 pound figure was allowed.

The panoramic camera system assumed by RAND is a variation of one developed by Fairchild Camera and Instrument Corporation for aircraft application. Fairchild has submitted a proposal to Lockheed for the camera portion of the pre-pioneer reconnaissance system and their material is included in this report.

1.3 Management Aspects

A complex undertaking such as the acceleration of the WS-117L negotiated program requires the contractor to make a careful survey of his capabilities and objectives before assumption of the many responsibilities of such a program. The Management of Lockheed fully appreciates the implications of this effort and is prepared to accept both the responsibility and challenge inherent in it.

In the past, Lockheed Aircraft Corporation has successfully undertaken design and production of many military and commercial aircraft, as well as several guided missile Weapon Systems. These undertakings have allowed the build-up of substantial resources, facilities, equipment, and skilled manpower. LMSD has accomplished a proportionate buildup in both its functional organizations and the WS-117L Project.

Using these people as a nucleus, LMSD will immediately implement additional and expedited efforts to assure that the accelerated program objectives are met. These include standardization of equipment designs, establishment of a close-knit, projectized team of managers, designers, fabrication specialists and test personnel---centrally located--- to assure concentration on problems peculiar to the WS-117L Program. It will also include simplification of drawing release procedures, specification compliance and acceptance procedures; as well as augmentation of test hardware equipment, necessary increase in facilities and maximum use of subcontractor capabilities.

To undertake this complex operation, it is assumed that Lockheed will be given immediate contractual authorization to proceed and will be provided necessary hardware and services (i.e., Atlas vehicles) as required. It assumes availability of appropriate Air Force facilities and supporting services at such locations as AFMTC and the IOC. The expedited approval by the Air Force of such things as subcontracts for purchase of hardware, establishment of DX priority and the approval of necessary overtime on the program is a basic requisite.

As a major consideration, it is assumed that full cooperation will be given by the Air Force in obtaining for the Contractor industrial and test facilities, machinery and equipment as needed in support of the acceleration of the program.

1.3.1 Priority Items

1. The following items are those on which an immediate "go-ahead" or priority action is required in connection with the implementation of an accelerated WS-117L Program:

   A. Subsystem A - Airframe

      (1) Authority to obtain required data on the shape of the front end of the Thor in early January.

   B. Subsystem B - Propulsion

      (1) Adequate priority authorization to LMSD by approximately 15 January for the purchase of pressurization system components.

      (2) Authority to approve Bell Aircraft's purchase orders for approximately $50,000 in engine materials and parts between 15 January and 1 February 1958.

      (3) Authority to negotiate a subcontract with Bell Aircraft for engines, ground handling equipment, and support services in time for a "go-ahead" date of 1 February 1958.

      (4) Require adequate priority to obtain solid ullage control rockets from Allegheny Ballistic within six months instead of presently scheduled delivery of 10 months.

   C. Subsystem D - Guidance and Control

      (1) Authority be granted by approximately 10 January 1958 to:

(a) Initiate a crash program on the horizon scanner

(b) Initiate a crash program on the proportional valve.

(c) Initiate a crash program on the inertial reference packages (or alternately, sufficient priority to be established to procure two Titan reference packages as GFE by 1 April, and one per month thereafter, until the inertial reference packages are available).

D. Subsystem C - Auxiliary Power

(1) Sufficient priority for Engineered Magnetics Company, manufacturers of 400-cycle inverters, to obtain delivery of a frequency standard crystal in 45 days, in lieu of present 90 day delivery schedule.

E. Subsystem F - Electronic Reconnaissance

[redacted]

F. Subsystem H - Ground-Space Communications

(1) Waiver of Military Specifications for drawings as well as JAN Specifications in connection with Philco-supplied equipment and services. Instead, specifications in accordance with good commercial practice should be authorized.

G. Ground Support Equipment

(1) Authority to proceed immediately from design to fabrication, without Air Force design approval, on servicing and handling equipment, and launch control and monitoring equipment.

H. Interim Tracking Stations (Cooke and Hawaii)

(1) TLM-18 concrete foundations are required by July 1958. The Air Force should either provide these or authority should be furnished for direct procurement by LMSD. It would be advantageous for the foundations and antenna installations to be contracted with the antenna subcontractor.

WS-117L PROGRAM ACCELERATION COST

1.4

A. FUNDING SCHEDL.

	Monthly Cost Expend.	Cum. Cost Expend.	Cum. CPFF Expend.	Cum. CPFF Expend. and Commitments
Jan. 58	[redacted]	$ 547,615	[redacted]	[redacted]
Feb.	[redacted]	2,486,390	[redacted]	[redacted]
March	[redacted]	5,237,977	[redacted]	[redacted]
April	[redacted]	8,932,827	[redacted]	[redacted]
May	[redacted]	13,323,807	[redacted]	[redacted]
June 58	[redacted]	17,995,725	[redacted]	[redacted]
July 58	[redacted]	22,933,390	[redacted]	[redacted]
Aug.	[redacted]	28,213,107	[redacted]	[redacted]
Sept.	[redacted]	34,153,150	[redacted]	[redacted]
Oct.	[redacted]	40,280,762	[redacted]	[redacted]
Nov.	[redacted]	46,359,216	[redacted]	[redacted]
Dec. 58	[redacted]	52,363,436	[redacted]	[redacted]
Jan. 59	[redacted]	58,319,742	[redacted]	[redacted]
Feb.	[redacted]	64,304,393	[redacted]	[redacted]
March	[redacted]	70,214,947	[redacted]	[redacted]
April	[redacted]	76,130,064	[redacted]	[redacted]
May	[redacted]	81,951,928	[redacted]	[redacted]
June 59	[redacted]	87,753,435	[redacted]	[redacted]

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[redacted]

1.4

WS-117L PROGRAM ACCELERATION COST

B. Price Summary

	Hours	Amount	Amount
Direct Labor-Management	162,299	[redacted]	
-Research & Development	1,472,102	[redacted]	
-Hardware	2,031,433	[redacted]	
Total Direct Labor	3,665,834	[redacted]	
Development Overhead		[redacted]	
Contract & Administrative Expense		[redacted]	
Total Labor & Overhead		[redacted]	[redacted]
Material		[redacted]	
Direct Charges		[redacted]	
Total Material & Direct Charges		[redacted]	[redacted]
Subcontract			[redacted]
Total Cost			[redacted]
Fixed Fee			[redacted]
Total CPFF			[redacted]

1.4

WS-117L PROGRAM ACCELERATION COST

C. Summary by Subsystem

	Hours	Labor & Overhead*	Material	Subcontract	Total
Management	162,299	$ 1,454,783	$ ---	$ ---	$ 1,454,783
Systems	1,501,249	13,456,636	2,856,032	261,000	16,573,668
Subsystem A	713,076	6,391,745	715,082	---	7,106,827
Subsystem B	244,721	2,193,587	255,549	10,108,530	12,557,666
Subsystem C	57,076	511,608	139,204	2,037,630	2,688,442
Subsystem D	169,554	1,519,818	284,638	578,724	2,383,180
Subsystem E	17,417	156,119	4,912	10,224,552	10,385,583
Subsystem F	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Subsystem G	---	---	---	609,000	609,000
Subsystem H	778,589	6,978,997	1,140,110	16,555,645	24,674,752
Subtotal	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

Direct Charges	3,574,625
Total Cost	[redacted]
Fixed Fee	6,637,758
Total CPFF	[redacted]

*At Project Average Rates

Subsystem A - Vehicle
Subsystem B - Propulsion
Subsystem C - Auxiliary Power
Subsystem D - Guidance & Controls

Subsystem E - Visual
Subsystem F - Ferret
Subsystem G - Infrared
Subsystem H - Ground-Space Comm.

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[redacted]

1.4

WS-117L PROGRAM ACCELERATION COST

D. Summary by Element

	Hours	Labor & Overhead*	Material	Subcontract	Total
Management	162,299	$ 1,454,783	$ ---	$ ---	$ 1,454,783
Research & Development					
Design & Development	471,062	$ 4,222,418	$ 530,119	22,477,182	$27,229,719
Test & Operations	868,982	7,789,227	263,519	1,033,816	9,086,562
Ground Support Equip.	126,672	1,135,440	576,484	1,356,488	3,068,412
Human Engineering	5,384	48,256	---	---	48,256
Q.P.R.I	---	---	---	---	---
Total R&D	1,472,100	$13,195,341	$1,370,122	$24,867,486	$39,432,949
Hardware					
Tooling & Mockup	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Fab. Assem. & Instal.	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Ground Support Fabr.	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Mfg. Services	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Total Hardware	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Subtotal	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Direct Charges					[redacted]
Total Cost					3,574,625
Fixed Fee					[redacted]
Total CPFF					6,637,758

[redacted]

*At Project Average Rates

1.5 Follow-on Reconnaissance Programs

The program presented here assumes ten Thor/WS-117L satellites fired at one per month starting October 1958. This is considered sufficient to provide a good start into pre-pioneer recoverable reconnaissance mission. From the standpoint of overall WS-117L system capacity, it is logical to continue firing Thor boosted versions of the WS-117L at least on the one-per-month basis and at even higher rates at such times as it is shown that, say, an infrared warning net can be performed using the Thor version.

The application of the present WS-117L vehicle to the Thor to provide an early recoverable reconnaissance capability was discussed above. This system will provide 300 pound payload capability on a polar orbit which is ample for pre-pioneer type visual reconnaissance.

In approximately a year subsequent to this capability the Atlas boosted reconnaissance systems should be available having useful payloads of over a ton. Thus, there must be a special reason for increasing the payload capability of the Thor in this later time period. Such can be justified only if:

a. There are unique applications for the Thor capitalizing on its relatively lower cost over the Atlas and,
b. If the methods used to provide additional payload capability are either developed under other programs or are also useful to Atlas boosted versions of the WS-117L.

Use of Polaris second stages as a stage intermediate between the Thor and the WS-117L will yield about 600 pounds useful payload with the Polaris A and 830 pounds with the Polaris B. Introduction of higher performance propulsion to the WS-117L vehicle will yield considerable increases in Thor/WS-117L vehicle payloads and will also be useful to the Atlas versions. Substituting UDMH to the present Hustler engine and increasing its area ratio to 20:1 will yield about 277 seconds and increase the payload from 310 to 430 pounds. Use of a fluorine/ammonia system at 340 seconds will yield about 800 pounds. Even higher specifics of 440 seconds (by fluorine/hydrogen) have been considered but the increase in tank weight using hydrogen may offset this improvement unless some new method (such as decomposition of high-hydrogen compounds) is found for hydrogen storage.

These higher specifics will not bring a commensurate increase on the Atlas due to the latter's load limitation. If, however, a structurally stronger booster of equivalent performance to the Atlas (such as the Titan) is employed to allow full benefit of a 340 second propulsion system (optimum size vehicle about 20,000 pounds) then payloads of the order of two tons can be realized. This is the sort of size needed for the recoverable capsules of manned satellites.

If both the Polaris intermediate stage and the WS-117L high performance (340) propulsion system is used, Thor booster satellites of 1300 pounds of useful payload at low altitudes and several hundred pounds at altitudes around 1000 miles are conceivable.

In answer to requirement a) then to what use can the Thor versions be put that are of a special nature? The most promising of these from an early standpoint is the long focal-length camera. The early RAND-type payloads will utilize fast film of about 40 lines/minute resolution (compared to 750 lines/minute for regular WS-117L applications) which can operate at very short exposure times of 1/4000 seconds. This allows for considerable uncompensated image motion and thus long focal lengths in a satellite. Combining this feature to that provided by the standard WS-117L system of a stabilized vehicle will allow even longer focal lengths to be employed. Focal lengths of 120 inches should be attainable without state-of-the-art.

In these long focal length cases it is logical to return only the film cannister and not the camera proper to keep the recovery system to a reasonable size.

The WS-117L ferret mission probably would be augmented advantageously by having a quick reaction capability-sort of a gap filler-special purpose type ferret systems. This would allow the regular Atlas-boosted versions to concentrate on overall surveillance type missions. Again the Thor's relatively lower cost might be of finite advantage in this type mission.

The infrared warning system (and later ICBM tracking system for AICBM) is one of the very important missions in the present WS-117L program. To provide continuous coverage for instantaneous warning of enemy ICBM'S will require networks of 30 vehicles or more. Because of random distribution effects, payload operational limitations, attrition, possible enemy countermeasures, it is conceivable that many vehicles will be needed each year. Higher altitudes will decrease the number needed which places a premium on a highly reliable, long duration (such as solar powered) payload at altitudes of around 1000 miles. Using the performance schemes discussed above may allow such a payload to be put up with a Thor. Whether this more sophisticated propulsion system will offset the lower cost of the Thor over the Atlas is not known at this time.

In conclusion it is believed that addition of the Thor recovery reconnaissance system to the WS-117L program will provide not only a very early reconnaissance capability but also a useful special purpose system and perhaps the most economical way of putting up part of the infrared warning network. The addition of physical recovery systems to the program will not only add much to its flexibility, but the experience gained through their use will pave the way for recovery of larger and more delicate payloads (such as a man) from satellite orbits.

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SECTION 2

MANAGEMENT CONSIDERATIONS

2. MANAGEMENT CONSIDERATIONS

2.1 Lockheed's Corporate Position

The Management of the Lockheed Aircraft Corporation fully appreciates both the vital national importance of successful acceleration of the WS-117L Program, and the inherent developmental difficulties associated with this complex Weapon System. Lockheed is prepared to accept this responsibility and challenge by devoting the essential high priority to providing its portion of manpower, facilities and capital resources necessary to insure timely and successful program accomplishment. Further, the contractor has determined that those necessary resources can be provided in consonance with the accelerated program.

2.2 Contractor's Established Capabilities

Lockheed Aircraft Corporation has been successfully engaged in the design and production of military and commercial aircraft under its present Management since 1932. In recognition of the rapid growth of Weapon System Research and Development requirements, the Corporation created the Missile Systems Division in 1953. From inception, this Division has been planned and directed to function as a prime Weapon System Contractor. In this capacity, it is supported to the fullest extent by the resources of the parent Corporation.

Successful achievement of the rigorous requirements and schedule, as proposed herein, is premised on the extensive resources in facilities, equipment, and the skilled scientific and technical personnel already devoted to the present WS-117L effort; and the successful experience already gained in the solution of technical, production, and operational problems associated with the X-17 Re-entry Test Vehicle Program, X-7 Ramjet Engine Test Program, X-7B Guidance Test Vehicle Program, XQ5 Target Drone System, and the Navy's Polaris

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Missile Program. Skills also available to this effort include the Engineering and Manufacturing Staffs of Lockheed's California Division, the creators of such products as the P-80, F-94, F-104 and the Electra Turbo-prop Transport.

2.3 Expedited Methods for Accelerated Program Accomplishments

In order to achieve the accelerated program accomplishments, LMSD will initiate expedited measures such as:

a. Basic efforts already underway in support of the current WS-117L Program will be advanced by immediate standardization of the vehicle structure and immediate release of usable preliminary hardware drawings into the fabrication shops.

b. A close-knit highly skilled team of designers, fabrication specialists and test personnel is being formed, centrally located, and provided with all necessary equipment. Utilization of maximum shop aids rather than Class "A" tooling and direction by a manager with full authority to make "on-the-spot" decisions affecting progress of the work including procurement of materiel, design changes and fabrication techniques is planned. Units will concentrate upon the first series of vehicles required to initiate full-fledged WS-117L vehicle flight tests in October, 1958. (The successful employment of this technique has been demonstrated within the Lockheed Corporation by similar action resulting in the development of the P-80 from a completion of preliminary design to first flight readiness in 137 days; and the more recent Jet Star Utility transport, an elapsed time from design inception to flight test of 34 weeks.)

f. LMSD facilities and/or personnel at Sunnyvale, Palo Alto, Van Nuys, and Santa Cruz, plus other Lockheed facilities operated by the California Division and Georgia Division will be utilized as required.

g. Maximum use will be made of appropriate subcontractor capabilities and outside production of components from suitable vendors.

2.4 Manpower and Skill Availability

Manpower and associated scientific and technical skill requirements have been determined available as necessary to support the program in accordance with the following premises:

a. LMSD personnel presently supporting the WS-117L effort provide the essential nucleus for effort requiring immediate go-ahead. These qualified personnel will be supplemented promptly with additional experienced personnel from within LMSD plus personnel obtained from both the California and Georgia Divisions of Lockheed, on either a transfer or loan basis as required. All such personnel currently are authorized "Secret" security clearances.

b. The National, State and Bay Area labor markets present suitable specialized talents in adequate quantities to satisfy anticipated requirements. Effective exploitation of this valuable asset is critically dependent upon Air Force support in expediting necessary security clearances for such "new hires" (See Assumptions).

c. In parallel with b. above, LMSD proposes to "projectize" the overall WS-117L effort in recognition of its critical importance and expanded scope, in contrast with the present "functional" organization arrangement which provided a broader base of available skills with wide-spread application of specialized talents. Action significant in this direction has already been taken on the part of Lockheed Management by assignment of increased authority and responsibility to the WS-117L Program Weapon System Manager of the Missile Systems Division as of 1 January 1958. Further centralization of supporting functions in both location and direct lines of authority will expedite materiel flow and execution of program operating plans.

d. The release procedure for all hardware drawings during the basic development phase of the program will be streamlined, dependent upon Air Force waiver of Specification requirements (See Assumptions). This expedient will require increased informal liaison between design and fabrication personnel with senior experienced personnel performing this function. An appreciable but acceptable increase in modification center re-work must be provided for.

e. Provisions will be made for the fabrication of additional hardware to permit parallel rather than sequential component fabrication, assembly and testing.

e. The Air Force will establish procedures for expedited handling of items requiring Air Force approval, particularly in regard to approval of subcontracts and the purchase of major items required in support of the proposed Program.

f. Provision will be made to permit LMSD to subcontract the construction of the superstructure and installation of a TLM/18 tracking radar at the IOC.

g. An Air Force aircraft, modified to accommodate special equipment requirements, and Air Force flight crews will be available for high altitude flights to assist in Ferret Subsystem tests. Such aircraft must be at the disposal of LMSD for a period not less than six months.

h. A DX priority for the Program will be established by the Department of Defense to support the contractor's scheduled program efforts.

i. Overtime efforts required to support the program will be approved by the Air Force. A basic forty-five (45) hour work week will be initiated immediately upon program go-ahead, with additional overtime requirements anticipated in critical planning, design, and fabrication areas.

j. Reasonable specification deviation authority will be granted as may be required to expedite early release of drawings into fabrication and to accommodate engineering changes in the course of manufacturing.

2.5 Assumptions

The accomplishment of this program is dependent on several vital assumptions. These are:

a. LMSD will be given contractual authority to proceed no later than 1 February 1958. Limited authority to initiate efforts on longer lead time high-priority items will be given by 15 January. (These high priority items consist of increased engine delivery requirements and associated accelerated development efforts; additional ground test vehicle assemblies; accelerated development of the Pioneer Visual Subsystem; accelerated procurement of Auxiliary Power Subsystem components; accelerated development of Pioneer Ferret Subsystem; accelerated development and production of ground support equipment with modification as necessary for WS-117L/Thor launching.)

b. Availability of necessary Thor vehicles, Douglas Aircraft Company Thor launching crews, and adequate technical assistance and cooperation from the Douglas Aircraft Company organization will be available.

c. Availability of necessary Atlas vehicles with Convair launch crews for launching operations at AFMTC and at IOC if required, plus adequate technical assistance and cooperation from the Convair organization will be available.

d. Availability of necessary Air Force facilities and supporting services necessary to support the Program at: (1) AFMTC, (2) IOC, (3) Hawaii Command and Tracking Station, and (4) Alaska Command and Tracking Station will be available.

2.6 Program Plan

LMSD's approach to accomplishment of program acceleration will be organized as follows:

2.6.1 Project Management

The Management activities at LMSD pertaining to the US-117L Program are defined as follows:

2.6.1.1 Weapon System Manager and Staff

This activity includes the central direction of the program by the Weapon System Manager, his direct Assistants, the Technical Director, technical consultants as appropriate, and the secretarial staff which reports directly to the Weapon System Manager and members of his immediate staff.

2.6.1.2 Program Plans and Controls

This activity includes the program planning, scheduling, budgeting, in-plant operations coordination, work definition, fiscal control, and reporting activities necessary for proper management of the Weapon System program. Included also is the establishment and operation of the Program Information Center.

2.6.1.3 Test and Operations Planning

This activity includes the planning and coordination of in-plant, STF, and flight test activities, planning for and coordination of ground support equipment design and manufacture, facilities and logistics planning, and training and QFRI. planning and coordination.

2.6.1.4 Technical Research and Development

This activity includes the planning and direction of the overall research and development effort required for the WS-117L Program.

Administration and Services

This activity includes the Weapon System office management, correspondence control, staff personnel administration, and supporting direct administrative service functions necessary to conduct the program.

2.6.2 System Consideration

2.6.2.1 Research and Development

System Design Studies

The following analyses and studies will be conducted in support of the overall WS-117L Development Program: Perform operations analyses to design Weapon Systems requirements and objectives; perform system synthesis operations to establish the design criteria for effecting WS-117L Operational requirements and objectives; plan and effect a program to accomplish the detailed system reliability studies for the WS-117L Program; conduct environmental research, prepare preliminary designs of possible environmental chambers and studies to establish effects of orbit environment characteristics on the vehicles; perform operations analyses to determine design requirements of Ground Systems; perform studies and system design requirements of the total ground systems.

System Test and Checkout

A considerable amount of system development test activities will be conducted which are not applicable to any single subsystem, but generally to a complete WS-117L vehicle. The developmental tests include those conducted at the LMSD in-plant facilities, the System Test Facility and at the flight test bases. Such tests include developmental tests associated with problems of orbit environment evaluation and thermal control, and comprehensive system test and checkouts on the captive test vehicles, the system test vehicles and each of the flight test vehicles.

Qualitative Personnel Requirements Information

The contractor will carry out the necessary effort required to prepare, publish and submit periodically to the Air Force detailed studies concerning the qualifications of and training required for operating personnel for the time period when WS-117L will be operationally employed.

2.6.2.2 Hardware

The contractor will furnish system hardware defined as those major assemblies such as vehicles, ground support equipment, models, and mockups and tooling which are comprised of or affects more than one subsystem and which is required in the conducting of the overall development programs for the WS-117L.

Tooling

The contractor will design and build various types of tooling fixtures required in the assembly operations for the various ground and flight test vehicles.

Assembly and Installation

The contractor will assemble the following types of vehicle assemblies in support of the WS-117L development programs: space utilization models; functional mockups; captive test vehicles and flight test vehicles. In addition to the system vehicles the contractor will fabricate, assemble and test system ground support equipment such as checkout equipment, launch monitor and control equipment, servicing equipment and handling and transportation equipment required by the various system vehicles at the LMSD in-plant, System Test Facility and at the flight test bases.

2.6.3 Subsystem Considerations

2.6.3.1 Airframe Subsystems

The Airframe Subsystem consists of all primary and secondary structure, propellant and pressurization tanks, aerodynamic fairing, structural supports, installation brackets and fittings, and the mechanical and electrical installations in the satellite not

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Flight Test Planning

The contractor will perform planning activities required in the establishment of the complete flight test program. This planning will include the determination of detailed test requirements and objectives so that system performance can be adequately demonstrated and overall development objectives achieved.

Tracking Station Operation

The contractor will conduct limited operation of the tracking stations at Cooke AFB and at the Hawaiian Station to permit use of the AN/TLM-18 and associated equipment at the time of the first flight in Program I. In addition an Alaskan station will be operated to provide tracking and command functions for the second flight of Program II-A.

Design of Government Facilities

The contractor will establish site selection criteria, for each of the government facilities required by the WS-117L system. Included is the provision of technical assistance, provision of design criteria and detailed designs of these facilities as required.

Ground Support Equipment Design

The contractor will conduct the design, of all those ground support items of equipment which are required for transporting and preparing the complete WS-117L vehicle for launching or ground test such as handling, transport, service, checkout and countdown.

Human Engineering

The contractor will accomplish the following activities in support of human engineering effort for the WS-117L system: determine the human engineering requirements for WS-117L; supervise and direct all human engineering activities for the WS-117L; provide continuous review of QPRI studies and reports; provide a program of man-machine evaluation of hardware where human operation is applicable.

2.6.3.3 Auxiliary Power Subsystem

The APU Subsystem consists of the energy source and power control conversion equipment necessary to furnish the electrical power required by all subsystems within the satellite vehicle from the time just prior to launch to the end of the vehicle's reconnaissance lifetime. The over-all subsystem design and development is being conducted at LMSD, whereas certain specific developments such as batteries, voltage regulators and inverters will be subcontracted to appropriate sources for these items.

2.6.3.4 Guidance and Control Subsystem

The Guidance and Control Subsystem is based upon the developement of equipment required to fulfill functions associated with each of five different phases of flight. These phases are Initial Boost, Coast, Orbital Boost, Reorientation, and Orbital Stabilization. Major equipments required therefore for the Atlas boosted vehicles are the ground-based General Electric Radio guidance system; the vehicle-borne Inertial Reference Package (consisting of a body-mounted gyro reference system and two accelerometers), an integrator, an attitude and time programmer, the auto-pilot, gas control valves, engine hydraulic actuators, and the horizon scanner. Thus the WS-117L Guidance and Control System is made up of a composite of ground-based radio guidance equipment, modifications to the ATLAS airborne guidance components and all components mounted in the WS-117L orbit vehicle. The horizon scanner and the Inertial Reference package will be developed by appropriate subcontractors. The additional orbit vehicle guidance and control equipment for use in Program I flight tests will be designed, developed or purchased and assembled by Lockheed. Both component and complete subsystem and weapon system tests will be performed in LMSD installations prior to delivery for flight test.

specifically included in the definition of Other Subsystems. Associated with the airframe are such hardware items as the space utilization model, functional mock-up, structural test vehicle, propulsion test vehicles and assemblies, and flight vehicles. The major portion of effort on this subsystem will be conducted at LMSD to enhance maximum integration of design, fabrication and assembly. The rapid acquisition of small components and hardware will be accomplished through extensive outside purchases. The scope of this work includes all analysis, preliminary design, detail design, development fabrication and test. It also includes the development of necessary ground support equipment.

2.6.3.2 Propulsion Subsystem

The Propulsion Subsystem consists of the orbital thrust rocket engine, the space-borne propellant pressurization, feed and loading systems (other than fluid and gas tanks), engine gimbals (but not gimbal actuation or power supply for these actuators) and the equipment required to start, stop and control thrust magnitude in response to an electrical signal from the ground or from the Guidance and Control Subsystem. It will also include any thrust producing devices and associated plumbing used for attitude and roll control (but not the electromechanical valves used to start, stop or regulate thrust of these devices, nor the actuators required to change the direction of thrust of such devices if required), and any auxiliary boost rockets required to establish proper ullage orientation in the fluid tanks and lines prior to and during start of the orbital thrust engine including the equipment required to start thrust of the auxiliary boost rockets. In addition, the Propulsion Subsystem will include all ground based items used for its testing, calibrating, check-out and servicing. All research, development and fabrication of the rocket engine will be performed by the Bell Aircraft Corporation. LMSD will perform over-all subsystem development including principal system tests and pre-flight tests.

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[redacted]

[redacted]

[redacted]

In the case of the Thor boosted vehicles the initial boost guidance is provided by the A-C Spark Plug inertial guidance system used in conjunction with the orbit vehicle equipment described above. The G. E. guidance equipment for the Atlas missiles and the A-C Spark Plug equipment for the Thor missiles are considered to be GFE.

2.6.3.5 Visual Reconnaissance Subsystem

The Visual Reconnaissance Subsystem consists of the satellite-borne equipment required to collect visual information, to process and store this information, and at the proper time to reconvert the stored information to an appropriate video signal for transmission to the ground by the Ground-Space Subsystem. The Visual Subsystem also includes the ground-based equipment required to take the output of the data link and reconstitute the video signal into photographic form, to screen the usable data from the waste, file the data by geographic reference and to provide such analysis as is required to check and control the operation of the subsystem. It also includes ground-based equipment required to service and calibrate the various elements of the Visual Reconnaissance Subsystem. A series of operational capabilities shall be attained in chronological sequence as defined below:

Pioneer Visual Reconnaissance Program

The Pioneer Visual Program will provide the ability to secure photographs of areas of potential military interest. These photographs as finally reconstituted on the ground, will be of such quality as to permit the resolution of the standard AF medium contrast test pattern as defined in Mil-Standard 150, with dimension W equal to 50 ft. The location of any part of any photograph shall be determinable with an error no greater than one mile.

Advanced Visual Reconnaissance Program

The Advanced Visual Reconnaissance Program shall provide a capability similar to the Pioneer Visual Program except that the maximum dimensions of the pattern to be resolved and the minimum

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ground lineal coverage to be retained are to be reduced by a factor of 6. The location accuracy will be increased to a maximum error of half a mile. The system may incorporate features to allow the programming of the camera to point to areas of specific interest.

Visual Surveillance Program

The Visual Surveillance Program leads to development of a continuous surveillance system which will keep Russia under constant scrutiny.

Primary effort of LMSD is applied to planning and directing the execution of the development program for the Visual Subsystem. Major hardware effort is being subcontracted to Eastman Kodak Company. Smaller subcontracts for a video recorder and TV feasibility studies are being let to other subcontractors with major capability in these fields.

2.6.3.6 Electronic Reconnaissance Subsystem

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2.6.3.7 Infrared Reconnaissance-Surveillance Subsystem

This infrared program has as an ultimate objective a system of satellites on orbit, placing unfriendly territory under continuous and complete surveillance. Such a system will have the capability (1) to detect ICBM launchings whenever and wherever they occur, and to immediately transmit this information to the ground, and to provide unambiguous warning of ICBM attack, (2) to track ballistic missiles during their burning stage with sufficient accuracy for trajectory and impact prediction in AICBM applications, and (3) to detect exhaust plumes of large air-breathing missiles and aircraft to provide early warning of attack by such vehicles and for surveillance of air traffic patterns as an indicator of the imminence of hostilities.

The over-all subsystem program is being directed at LMSD. In addition LMSD is conducting operational analyses on over-all infrared systems, performing studies on target detection capabilities and limitations of satellite-borne infrared sensing systems, investigations of advanced applications of satellite infrared systems and establishment of operational utility of very high altitude orbits. In addition, there are several major efforts underway through subcontracts with Baird-Atomic, Inc., General Mills, Inc., Eastman Kodak Company and Aerojet-General Corporation for various phases of the program.

The major effort during the contract period for hardware will be minimal prototype development. Some development hardware will be flight tested; however, it will be under controlled environmental conditions. The primary effort will be a study to determine the availability of components and establishing design criteria for fabrication of special hardware items. There will be no tooling or special test equipment required in the fabrication of this equipment other than that mentioned in the subcontractor section dealing with this subsystem.

2.6.3.8 Ground-Space Communications Subsystem

The Ground-Space Communications Subsystem consists of equipment to perform the following six functions for the WS-117L Weapon System:

Acquisition & Tracking: To locate the vehicles in time and space and predict their location at future times. This is basically a tracking and computation function.

Telemetry System: To transmit telemetry data on equipment operation and environmental conditions from the vehicle to the ground stations where it is received and recorded. Long lived and reliable telemetering equipment will be developed to perform this function.

Reconnaissance Data Link: To transmit reconnaissance data gathered by vehicles to the ground stations, then record this data at the ground stations and store it or relay it to the Central Intelligence Station as required.

Vehicle Antenna Systems: The requirements of antenna design will be such that an acceptable pattern will be provided commensurate with the expected vehicle space attitude with respect to the earth's surface during ascent, erection, and on orbit.

Intra and Inter-Station Communication: Provide for intra-and inter-station communications. This can be accomplished in many different ways, e.g., by telephone lines, radio relay, forward scatter links, etc. Both narrow and wide band links will be required.

Computers, Timer, and Command System: Prepare and transmit from the ground stations to the vehicle command signals which schedule the future performance of the various vehicle functions. Generate accurate timing signals in the vehicle and on the ground for synchronizing operations and for accurate programming.

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The ground-space communication subsystem shall also include all those items of equipment required to service, test monitor, and calibrate the elements of the subsystem defined above.

For early flights, an interim capability will be established by making maximum use of available range tracking, telemetry, and other instrumentation. Existing vehicle-borne equipment will be utilized wherever practicable. During this contract period, however, the major subsystem effort will proceed concurrently in the study, investigation, research, and development of advanced equipment compatible with the system requirements.

LMSD will direct the over-all design, development, and test of the Ground-Space Communications Subsystem but will subcontract major elements as required to assure early availability of equipments. As the major subsystem subcontractor, the Philco Corporation will have the responsibility for the development of the integrated subsystem. Philco will develop computers, vehicle and ground data links, ground command links, and intra- and inter-communications systems. LMSD will develop vehicle-borne telemetry equipment, command links, antennas, and destruct systems as required.

As a part of the development of the Ground-Space Communications Subsystem, LMSD will perform extensive in-plant tests on components and the assembled subsystem. Upon incorporation into a flight vehicle, this subsystem will also receive comprehensive testing in associated work, payloads, and other associated equipments.

SECTION 3

TECHNICAL DEVELOPMENT PLAN

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3.1

LMSD-2832

RDB PROJECT CARD

TYPE OF REPORT

REPORT CONTROL SYMBOL [illegible]

1. PROJECT TITLE
Advanced Reconnaissance Weapon System 117L
(Accelerated Program)

2. SECURITY
Secret and
Top Secret

3. PROJECT NUMBER
WS-117L

4. INDEX NUMBER

5. REPORT DATE
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7. SUBFIELD OR SUBJECT SUBGROUP

7A. TECH. OBJ.

8. COGNIZANT AGENCY
Air Research and Development Command

9. DIRECTING AGENCY
Hq ARDC
Ballistic Missile Division

OFFICE SYMBOL

TELEPHONE NO.

10. REQUESTING AGENCY
Hq USAF

11. PARTICIPATION, COORDINATION, INTEREST

USAF	USN
AMC-P	CNO-I
APGC-P	USA
ATC-P	C/S-I
SAC-C	Other
ADC-C	CIA-I

12. CONTRACTOR AND/OR LABORATORY
LOCKHEED AIRCRAFT CORP.
MISSILE SYSTEMS DIVISION

CONTRACT/W.O. NO.

13. RELATED PROJECTS
WS-107A
WS-315A

14. DATE APPROVED

15. PRIORITY

16.

17. EST. COMPL. DATES

RES.

DEV.

TEST

OP. EVAL.

18. FY	FISCAL ESTS. (in $)

19.

20. REQUIREMENT AND/OR JUSTIFICATION

The WS-117L Advanced Reconnaissance System is now under development in accordance with the WS-117L Statement of Work, WDTR 57-131 (SECRET) as modified by the recent negotiations for the Revised Contract Cost Proposal, LMSD 2786, (SECRET). In conformance with the national need for accelerating and augmenting missile programs for strategic warfare, the 117L program must be accelerated and augmented. This accelerated program requested by WDTR 57-453 (SECRET) in reply to LMSD-36469 (SECRET) is designed to fulfill, within the earliest possible time scale, the military requirement outlined in General Operational Requirements (80) SA-2C dated 11 March 1955 and System Requirement 5 dated 17 October 1955, stated in the latter document as follows:

"Provide continuous (visual, electronic, or other) coverage of the USSR and satelite nations, for surveillance purposes. Timeliness of receipt of the intelligence information is essential, with daily reconnaissance coverage at high resolution the ideal. In consideration of the

21. MRC	SM	CM	SC & P	X	L	C

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LOCKHEED AIRCRAFT CORPORATION

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MISSILE SYSTEMS DIVISION

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R&D PROJECT CARD
CONTINUATION SHEET

SECURITY CLASSIFICATION

LMSD-2832

1. PROJECT TITLE Advanced Reconnaissance Weapon System 117L (Accelerated Program)	2. SECURITY OF PROJECT Secret and Top Secret	3. PROJECT NUMBER WS-117L
	4.	5. REPORT DATE 6 January 1958

requirement for earliest availability of the Advanced Reconnaissance System, the engineering progression and Air Force acceptance should be from the lesser to the greater resolution."

The types of intelligence required, in order of priority are:

1. Strategic Warning
2. Enemy Military Forces in Being
3. Enemy Military Stockpiles of Thermonuclear-Atomic Weapons
4. Enemy Logistics Capabilities
5. Enemy Industrial War Capabilities

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SECURITY CLASSIFICATION

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Section 3

21a. Military Characteristics

The military characteristics of the 117L accelerated program are essentially unchanged from those forming the basic concept for the present 117L program and are described in MSD-2011. The approach is somewhat modified by the use of the 315A Series IV missile to boost the 117L vehicle for earlier orbiting flights.

21b. Approach to an Early Recoverable Reconnaissance System

In order to augment the main 117L program and obtain reconnaissance data at the earliest possible date, operational recoverable reconnaissance vehicles will be launched at appropriate locations. A 315A series IV missile will supply the first stage of propulsion. The 117L vehicle will supply the second stage of propulsion to achieve orbital velocity following a short coast period after separation. The orbit to be established will be essentially circular at an altitude of approximately 135 miles for the main task of reconnoitering USSR territory above 45 degrees north latitude.

Immediately after establishment of orbit, the vehicle and camera package are oriented to a predetermined attitude. The camera package is then caused to spin at approximately 18 revolutions per minute and is separated from the vehicle. Thereafter the camera package will maintain a fixed orientation in inertial space as it orbits about the earth. The rotation of the package provides stability and the spin is used by the camera to scan and photograph the earth beneath the path of the satellite at appropriate intervals during the period of travel over the area to be reconnoitered. Approximately four days operation by one or more vehicles will furnish complete photographic coverage of the USSR above 45 degrees north latitude. After a sufficient number of passes have been made by a vehicle, the reentry and recovery phase of the mission is initiated. On the last circumnavigation the camera package will pass near the zenith over a tracking station. A recovery signal will then cause reentry to be initiated by the impulse of a solid propellant rocket. The impulse so imparted to the package will modify the orbit so that the package reenters the earth's atmosphere. During passage through the atmosphere, the package slows down to subsonic velocity before impacting in the ocean in a predetermined area. It will be retrieved after being detected and located by available radio and sonar methods.

Data to be obtained from the recovered film will be similar to the data to be obtained from the Pioneer Visual System except that the relative location of targets in a single sweep will be less precise, and the time lag between acquisition of data by the camera and start of data processing must of necessity be much greater due to the sequential nature of the complete read-in and recovery operations.

Subsystems

Vehicle. The vehicle subsystem consists of the space frame structure of the final stage, the mating details of the vehicle-booster stages, the vehicle-camera package, the reconnaissance package structure, and its reentry shield. The space frame structure also includes propellant and pressurization tankage. The existing vehicle design for the present program will be used and modified only where absolutely necessary to provide compatibility with the reconnaissance package and Thor booster.

Propulsion. The "XLR-81 Hustler" engine as presently contracted for will be used.

Auxiliary Power. Conventional electro-chemical batteries will be used.

Guidance and Attitude Control. The lightweight interim inertial guidance system will be used in conjunction with the ACSP inertial guidance system in the 315A Series IV missile. Reference for attitude control of the vehicle during coast, during orbital thrust, and at pitch-over will be obtained by means of a horizon scanner.

The camera package is inherently stable in inertial space during the mission due to its spin. The gravitational forces and aerodynamic forces encountered by the camera package during the mission life will not unduly change the orientation of the package.

Visual Reconnaissance. The camera makes use of the spin of the package to scan the flight path from side to side through an angle of 45 degrees each side of vertical. The camera will be able to resolve dimensions of about 60 feet at an orbital altitude of 135 miles.

Ground-Space Communication. The reconnaissance package will carry equipment to enable ground stations to acquire and track it in space, to initiate the recovery phase, to receive selected information about internal functions of the package and vehicle by telemetry, and to detect and locate the reconnaissance package for recovery purposes after it has returned from orbit to the earth's surface.

3.2 General Design Specifications

3.2.1 General

3.2.1.1 Statement of the Problem

The attainment of program goals is dependent on establishment of a firm plan for ground and flight tests which will permit logical development of all required equipments and human capabilities. The program of necessary flights is outlined in Table 3-1 of vehicle flight test objectives.

Table 3-1

LMSD WS-117L ACCELERATED PROGRAM

Program I. AFMTC Launch -- Effective Launching Direction, 108° True

FLIGHT NO.	PRIMARY FLIGHT TEST OBJECTIVES (TEST AND EVALUATION OF ITEMS BELOW)
No. 1 (Oct. 1958; Thor Booster; 7,000 lb OTV; Orbit Try)	(1) OTV Propulsion System, (2) Separation Mechanism, (3) Orbital Vehicle and Adapter Systems, (4) OTV Telemetry Systems (Interim), (5) Ascent Guidance, Extrapolator, and Transition Guidance and Control, (6) Interim OTV Auxiliary Power Supply System, (7) Data Acquisition and Tracking Systems at IOC and Hawaii (Interim), (8) Thor Booster System, (9) Ground Handling, Check-out and Launch Systems.
No. 2 (Nov. 1958; Thor Booster; 7,000 lb OTV; Orbit Try)	(1) OTV Propulsion System, (2) Ascent Guidance, Extrapolator, and Transition Guidance and Control Systems (Interim), (3) Reorientation and Orbit Attitude Control System, (4) Separation Mechanism, (5) Orbital Vehicle and Adapter Systems, (6) OTV Telemetry Systems (Interim), (7) OTV Auxiliary Power Supply System (Interim), (8) Data Acquisition and Tracking Systems at IOC and Hawaii (Interim), (9) Thor Booster System.
No. 3 (Dec. 1958; Thor Booster; 7,000 lb OTV; Orbit Try)	(1) OTV Propulsion System, (2) Ascent Guidance, Extrapolator, and Transition Guidance and Controls Systems (Interim), (3) Reorientation and Orbit Attitude Control System, (4) Components of the Orbital Attitude Damping Systems, (5) Components of the Environmental Control Systems, (6) Separation Mechanism, (7) Orbital Vehicle and Adapter Systems, (8) OTV Telemetry Systems (Interim), (9) Data Acquisition and Tracking Systems at IOC and Hawaii (Interim).

Table 3-1, (Cont'd)

FLIGHT NO.	PRIMARY FLIGHT TEST OBJECTIVES (TEST AND EVALUATION OF ITEMS BELOW)
No. 4 (Feb. 1959; Thor Booster; 7,000 lb OTV; Orbit Try)	(1) OTV Propulsion System, (2) Ascent Guidance, Extrapolator, and Transition Guidance and Control Systems (Interim), (3) Reorientation and Orbit Attitude Control System, (4) Components of the Orbital Attitude Damping System, (5) Components of the Environmental Control System, (6) Data Acquisition and Tracking Systems at IOC and Hawaii (Interim).
No. 5 (April 1959; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) Ascent Guidance, Extrapolator, and Transition Guidance and Control Systems (Interim), (2) Separation Mechanism, (3) Orbital Vehicle and Adapter Systems, (4) Environmental Control System, (5) Atlas Booster System, (6) Ground Handling, Check-out and Launch Systems.
No. 6 (June 1959; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) Ascent Guidance, Extrapolator, and Transition Guidance and Control Systems (Interim), (2) Orbital Attitude Damping System, (3) Demonstrate Effectiveness of ICBM Attack Alarm System Components and Techniques, (4) Separation Mechanism, (5) Orbital Vehicle and Adapter Systems, (6) Environmental Control System, (7) Atlas Booster System, (8) OTV Auxiliary Power Supply System.
No. 7 (July 1959; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) Ascent Guidance, Extrapolator, and Transition Guidance and Control Systems (Interim), (2) Orbital Attitude Damping System, (3) Demonstrate Effectiveness of ICBM Attack Alarm System Components and Techniques, (4) Separation Mechanism, (5) OTV Auxiliary Power Supply System.
No. 8 (Aug. 1959; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) Orbit Attitude Damping System, (2) [redacted] (3) Components of the UHF Tracking and Command System, (4) Components of Advanced OTV Telemetry System.
No. 9 (Sept. 1959; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) Components of the Advanced Guidance System, (2) [redacted] (3) Components of the Pioneer Visual System, (4) Components of Advanced OTV Telemetry System.
No. 10 (Oct. 1959; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) Components of the Advanced Guidance System, (2) Components of the Pioneer Visual Reconnaissance System, (3) UHF Tracking, Telemetry Command, Timing, Sequencing and Wide-band Data Transmission Systems.

Table 3-1, (Cont'd)

FLIGHT NO.	PRIMARY FLIGHT TEST OBJECTIVES (TEST AND EVALUATION OF ITEMS BELOW)
No. 11 (Nov. 1959; Atlas Booster; 9,300 lb OTV Orbit Try)	(1) UHF Tracking, Telemetry Command, Timing, Sequencing and Wide-band Data Transmission Systems, (2) Pioneer Visual Reconnaissance System Test Package, (3) Components Advanced Guidance System.
No. 12 (Dec. 1959; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) UHF Tracking, Command, Timing, Sequencing and Data Transmissions, (2) Pioneer Visual Reconnaissance System Test Package, (3) Components Advanced Guidance System.
No. 13 (Jan. 1960; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) Pioneer Visual Reconnaissance System Test Package, (2) Data Acquisition and Tracking Systems at IOC and Hawaii, (3) UHF Tracking, Command, Telemetry Timing, Sequencing and Wide-band Data Transmission Systems.
No. 14 (Feb. 1960; Atlas Booster; 9,300 lb OTV; Orbit Try)	(1) [redacted] (2) [redacted], Timing, Sequencing and Data Transmission Systems.

Program II. Pioneer Visual -- Cooke High Latitude Launch

FLIGHT NO.	PRIMARY FLIGHT TEST OBJECTIVES (TEST AND EVALUATION OF ITEMS BELOW)
No. 1, Mar.'60 No. 2, May '60 No. 3, July'60 No. 4, Sept.'60 No. 5, Nov.'60 All Flights with Atlas Booster 9300 lb Vehicle	(1) The successful operation of the complete Pioneer Visual Reconnaissance System. (This objective includes the highly accurate collection and processing by the vehicle system of required visual data, the satisfactory transmission of the data to specified ground stations, and finally, the recording and distribution of the data for evaluation purposes.)

Table 3-1, (Cont'd)

Program IIA. Physical Recovery of Visual Payload

FLIGHT NO.	PRIMARY FLIGHT TEST OBJECTIVES (TEST AND EVALUATION OF ITEMS BELOW)
No. 1 (Jan. 1959; Thor Booster; 7700 lb Vehicle; 400 lb Package; AFMTC Launch; 135 Mile Orbit; Low Latitude)	(1) Compatability of Thor Booster with 117L Vehicle, as modified to carry Visual Recovery Payload Package, (2) Recovery capsule's spin and separation mechanisms, (3) Complete Capsule Spin and Separation Systems, (4) Capsule tracking and ranging system, including capsule beacon and ground equipment at IOC and Hawaii, (5) Characteristics and possible errors of capsule orbit, (6) Capsule telemetry and tape recording equipment for measurement of internal and external temperatures during orbit and reentry; also for measuring capsule attitude and acceleration, (7) Capsule reentry protective measures, (8) Physical recovery techniques, utilizing ground command transmitter, capsule mounted recovery rocket system, floating beacon for sea recovery, lights, dyes, markers, etc., (9) Operation of camera and associated mechanisms.
No. 2, Mar.'59 No. 3, Apr.'59 No. 4, May '59 No. 5, June'59 No. 6, July'59 All Flights with Thor Booster; 7450 lb Vehicle; 300 lb Capsule; Cooke Launch; 135 Mile Polar Orbit	(1) Capability of Thor Booster and 117L Vehicle to successfully launch the recovery capsule into a polar orbit, (2) Complete capsule spin and separation systems, (3) Capsule tracking and ranging system, including capsule beacon and ground equipment in Alaska, (4) Characteristics and possible errors of capsule orbit, (5) Capsule telemetry and tape recording equipment for measurement of internal and external temperatures during orbit and reentry; also for measuring capsule attitude and acceleration, (6) Capsule reentry protective measures, (7) Physical recovery techniques utilizing ground command transmitter, capsule mounted recovery rocket system, floating beacon for sea recovery, lights, dyes, markers, etc., (8) Operation of camera and associated mechanisms, (9) The effectiveness of a recoverable payload, visual reconnaissance system when operating over known land masses, (10) Operation of camera during different periods of lifetime of different capsules in order to demonstrate the ability to secure complete photographic coverage.

3.2.1.2 Approach

Introduction

In order both to accelerate and augment the present WS-117L Program, an early booster availability is a necessity. The Thor (WS-315A, Series IV) missile can provide a boost capability for the WS-117L vehicle as presently designed if a reduced payload capability is accepted. A chart of WS-117L Thor performance is shown in Figure , Section 4. This payload capability is sufficient to provide early prove-in flights of the WS-117L vehicle guidance, control, APU, and propulsion system together with some WS-117L ground components in support of the accelerated program. This payload capability is also sufficient for an early recoverable reconnaissance system similar to the RAND reported in Reference 1. The two programs are mutually supporting and exclude any "dead end" developments. In addition to providing the early recoverable reconnaissance system, the WS-117L/Thor combination has the potential of being a more economic operational system for other special purpose payloads to be used in conjunction with the high-performance, WS-117L/Atlas, visual-reconnaissance system. Since the basic WS-117L hardware is common to both the current and the accelerated programs, manpower and technical skill is conserved.

Acceleration Program

The early availability of the 315A Series IV missile permits early engineering test flights of the WS-117L vehicles. These early test flights will confirm the design of the WS-117L vehicle and propulsion system and the interim guidance and control system. After design confirmation of the vehicle, the instrumentation of later flights with both the 315A Series IV missile and the SM-65C booster can be used to increase knowledge of the performance of Subsystem components, and provide payload capability for a recoverable reconnaissance system by using a concept proposed by the RAND Corporation.

Basically the concept consists of a recoverable reconnaissance package, placed in an orbit passing over the poles of the earth. The package is stabilized in inertial space by spinning it at a rate of about 18 rpm. The attitude is such that it is horizontal as it passes over the territory to be reconnoitered. The rotation of the package, in addition to providing stability, causes the camera to scan the path of the satellite from side to side as it proceeds in orbit. After a suitable number of passes over the enemy territory, the package is caused to reenter the earth's atmosphere and impact into the ocean where it is recovered and the film analyzed for intelligence data.

Lockheed Aircraft Corporation has adopted in principal the RAND concept for reconnaissance. The 315A Series IV booster together with the WS-117L vehicle and a RAND-type recoverable reconnaissance system payload will provide satellite reconnaissance data at the earliest possible date.

Operational Aspects of the Rand-type Recoverable Reconnaissance System

In order to cover completely the territory of interest in the USSR with the least number of missiles it has been determined that an orbit altitude of approximately 135 miles is desired. Four vehicles operating over a period of four days will provide complete coverage of the USSR from 45 degree north latitude to the North Pole. The decrease in orbit altitude due to aerodynamic forces is acceptable, being approximately 12 miles in four days. An Alaskan site will be a suitable location for the tracking station which will also initiate recovery. The impact will be approximately 1500 miles past the point at which the reentry rocket is initiated. The CPE of impact will be approximately 30 miles. Suitable SOFAR, radio and visual aids will permit Air Force flyover or Naval support forces to effect surface recovery.

3.2.2 Description

3.2.2.1 Vehicle

The vehicle subsystem consists of the aerodynamically shielded space platform. This includes structure to accommodate the other subsystems such as the reconnaissance system, the guidance and control system, the auxiliary power system, and the propulsion system. The vehicle structure includes the propellant and pressurization tankage. The booster mating structure also is considered as a part of the vehicle design problem.

The vehicle design must meet the following requirements:

a. Provide for the effects of environmental factors.

b. Accommodate the different payloads and associated equipment.

c. Accommodate the booster selected for first-stage propulsion, and provide second stage propulsion to attain orbital velocity.

d. Provide for proper mating and separation of booster and vehicle stages and also provide for spin up and separation of the payload stage for the recoverable reconnaissance system.

e. Optimize equipment packaging to fulfill attitude control and environmental control requirements.

3.2.2.2 Propulsion

Modified project Hustler XLR-81, 15000 pound thrust, pump-fed engines having a 263 lb sec/lb (vacuum) specific impulse with IRFNA and JP-4 propellant are being procured for the Engineering Prototype Test vehicle systems. The engine will be gimbaled for attitude control during thrust. Roll control will be maintained by auxiliary attitude control gas jets. These gas jets furnish attitude control during coast and effect pitch down after second stage burnout.

The performance of the propulsion system is sufficient to provide instrumentation payloads for initial engineering tests with the 315A Series IV booster. This performance is sufficient for the recoverable reconnaissance mission on a polar orbit at an altitude of 135 miles. A program improvement of additional payload capability can be provided by a relatively simple specific impulse improvement to 277 lb sec/lb (vacuum) by changing the propulsion system to use UDMH instead of JP-4 while increasing the nozzle expansion ratio from 14.8/1 to 20/1.

A general study of propulsion systems will be maintained to assure prompt recognition and integration of new developments such as fluorine, which will improve future vehicles.

3.2.2.3 Auxiliary Power

The auxiliary power subsystem for the engineering test vehicle and recoverable reconnaissance system vehicles and payload will be based upon the use of conventional electro-chemical battery units. Other power sources such as secondary batteries in conjunction with solar conversion and nuclear power sources are being developed as previously planned and will be incorporated in later vehicles.

3.2.2.4 Guidance and Control

Guidance and control of the vehicle may be divided into several phases. These are:

a. The boost phase.
b. Transition or coast phase.
c. Orbital boost phase.
d. Reorientation phase.
e. Steady-state orbit.

Guidance and control during the boost phase of the THOR boosters will be accomplished by the AC Spark Plug inertial guidance system since low-eccentricity orbits are required at the low altitude (135 statute miles) which requires a nearly circular orbit. For higher orbits (300 statute miles) it may be desirable to increase the booster performance by removing the ACSP guidance system to afford a greater payload capability. Guidance and control during the boost phase of WS-117L/Atlas flights will be as previously planned.

After separation the interim guidance system as presently envisioned for the WS-117L system will be used. This will utilize a horizon scanner in conjunction with an attitude programmer to keep the thrust vector of the vehicle horizontal.

It will also use an integrating accelerometer to measure the magnitude of velocity gained during orbital boost and initiate cutoff at the proper time. Pitch down to the proper attitude prior to payload spin up and separation of the recoverable reconnaissance system will be performed according to program.

The orbit stabilization system and the more precise guidance systems will be included in the program as previously planned.

3.2.2.5 Visual Reconnaissance

The early engineering test flights will not provide visual reconnaissance. The Pioneer and Advance Visual Systems will remain essentially as planned.

The Recoverable Reconnaissance system will contain a camera being designed by Fairchild. This will provide an early reconnaissance capability with a resolution essentially the same as that to be provided by the Pioneer Visual system with a reduced accuracy in target location data with an increased time between acquisition of data and data processing.

3.2.2.6 Electronic Reconnaissance

[redacted]

3.2.2.7 Infrared Surveillance

Study of the possibilities of the infrared system will continue as planned.

3.2.2.8 Ground-Space Communications

The Ground-Space communications subsystem includes provisions for:

a. Acquisition and tracking of the orbiting vehicle or the visual reconnaissance package.

b. Command of the vehicle or payload functions from a ground station.

c. Reception of data from the vehicle at the ground station.

d. The necessary inter-station communications.

The ground-tracking and command stations for the first engineering test flights and the Recoverable Reconnaissance system flights will be located in Hawaii and Alaska respectively. Air Force fly-over or Naval support forces for surface recovery will be located in the Pacific Ocean off the West Coast of the United States.

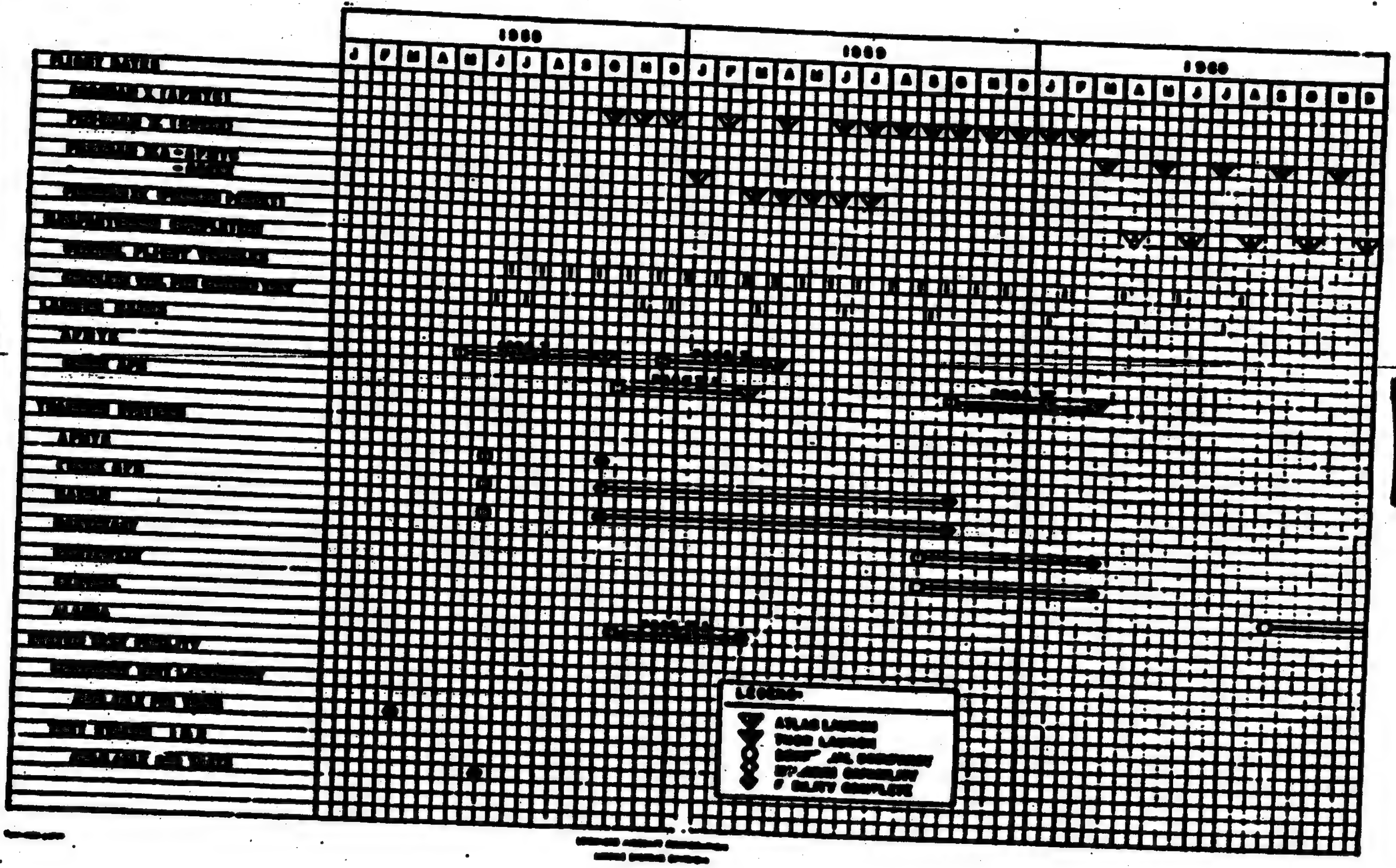
Studies for tracking systems and ground station site selection for later operational vehicles are proceeding as planned.

3.2.2.9 Recovery Program

The recoverable reconnaissance system will require either Air Force or Naval support forces to detect, locate, retrieve, and deliver the recovered packages. The vessels employed may be either surface vessels or submarines. The impact area of the reconnaissance package will be an area approximately 5 by 25 miles. After impact the reconnaissance package will provide active signals to permit recovery. These signals will be SOFAR signals and radio signals provided by a beacon. Emission of fluorescein dye will also provide for passive visual detection.

3.2.2.10 Data Handling

The subject of data processing and handling for the recoverable reconnaissance system will be treated in a separate document. Planning for film rectification equipment to handle known errors is being accomplished by Fairchild Camera. An analysis to determine the extent to which this system will fulfill intelligence requirements must be based on the capabilities of the rectification equipment.



Milestones - WS-117L Accelerated Program

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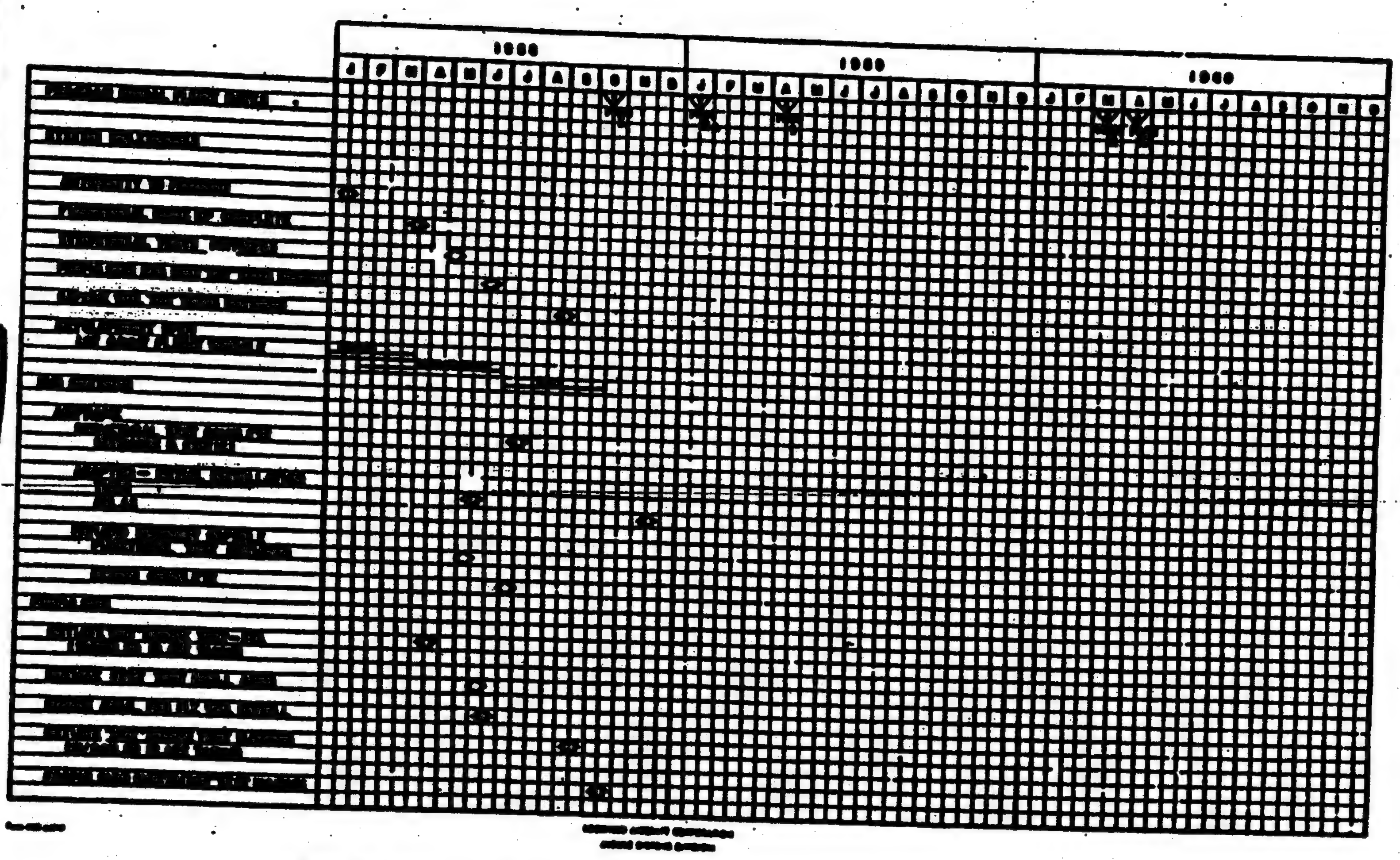

WS-117L System and Subsystem Milestones - Accelerated Program

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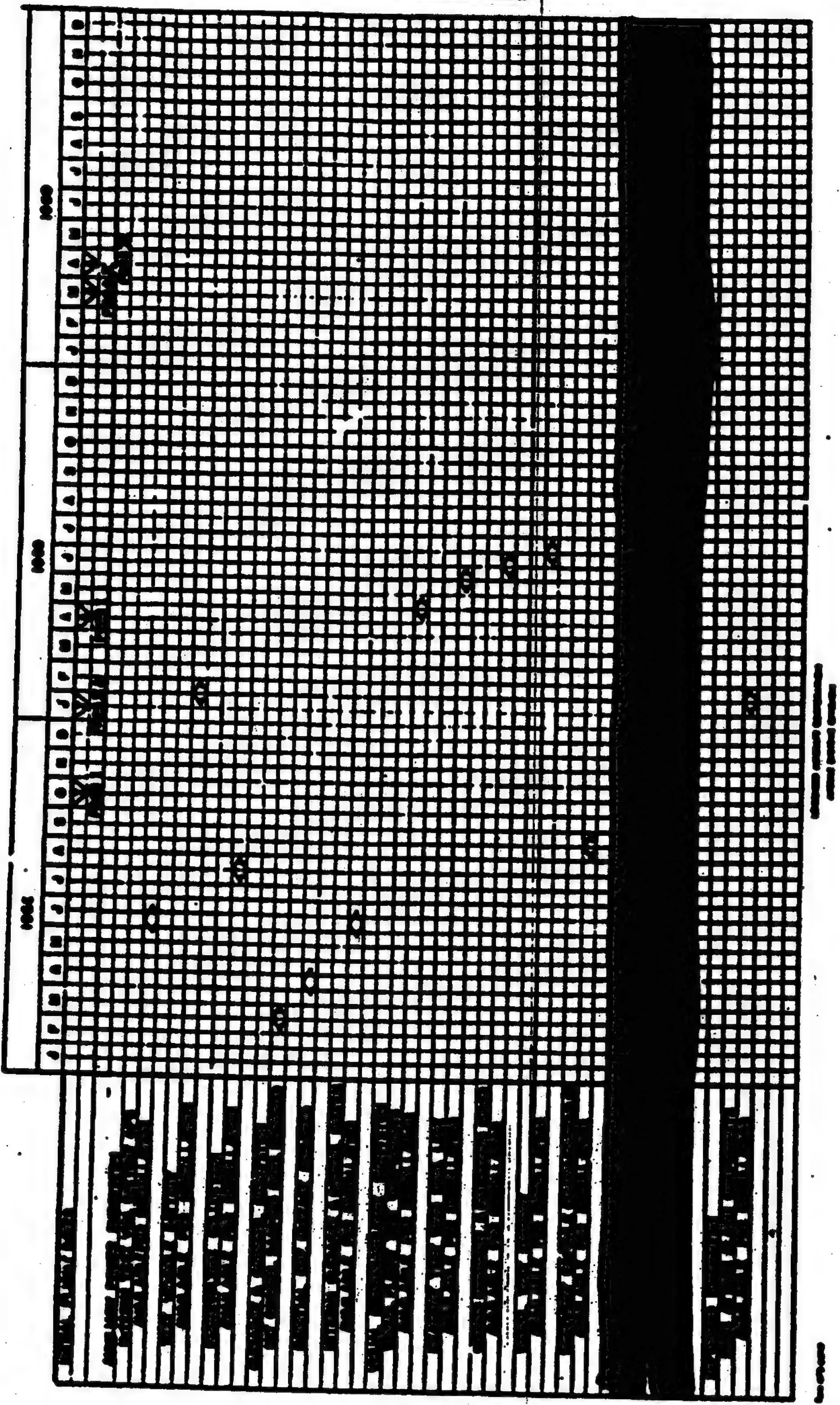

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WS-117L - Subsystem Milestones - Accelerated Program

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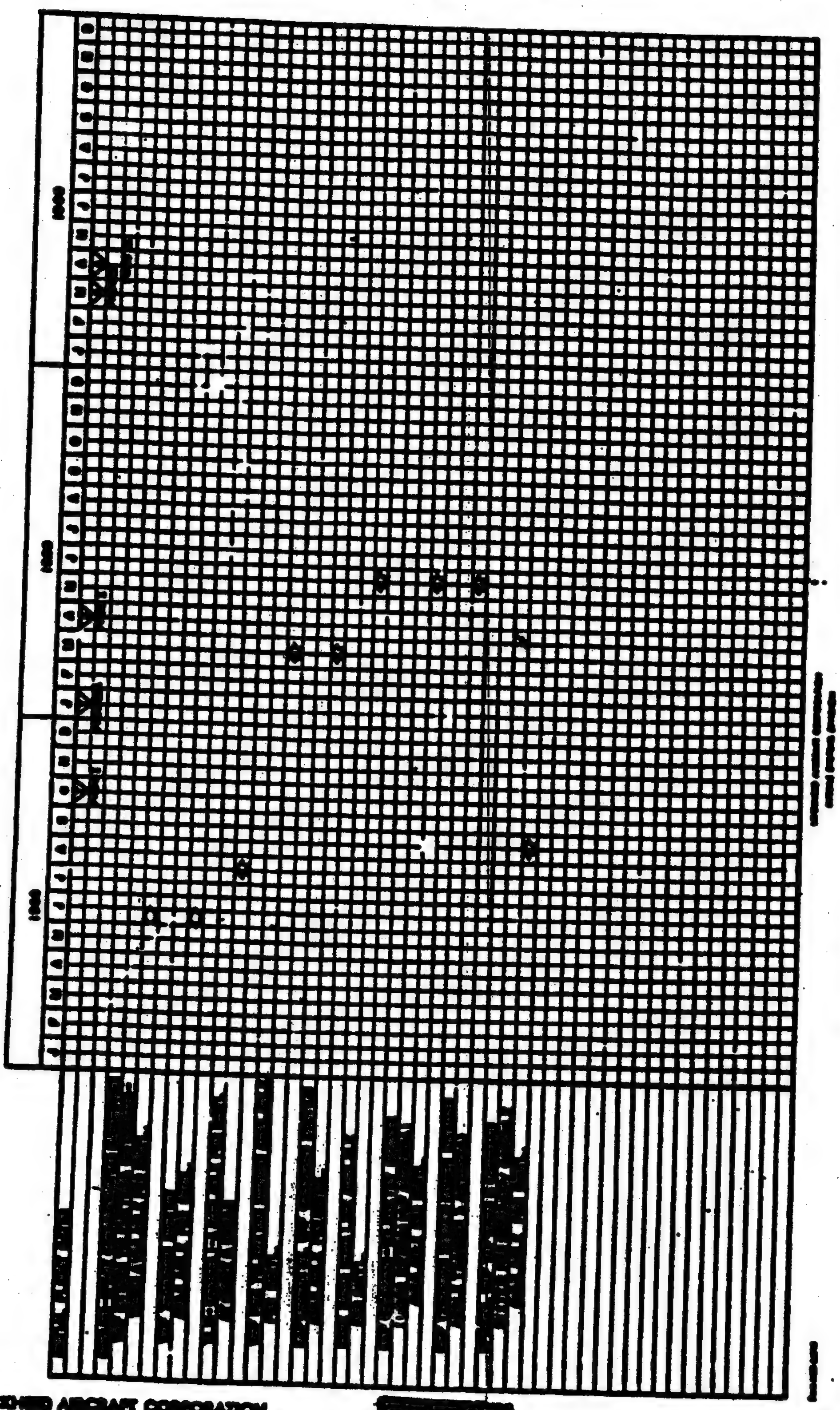

WS-117L Subsystem Milestones - Accelerated Program

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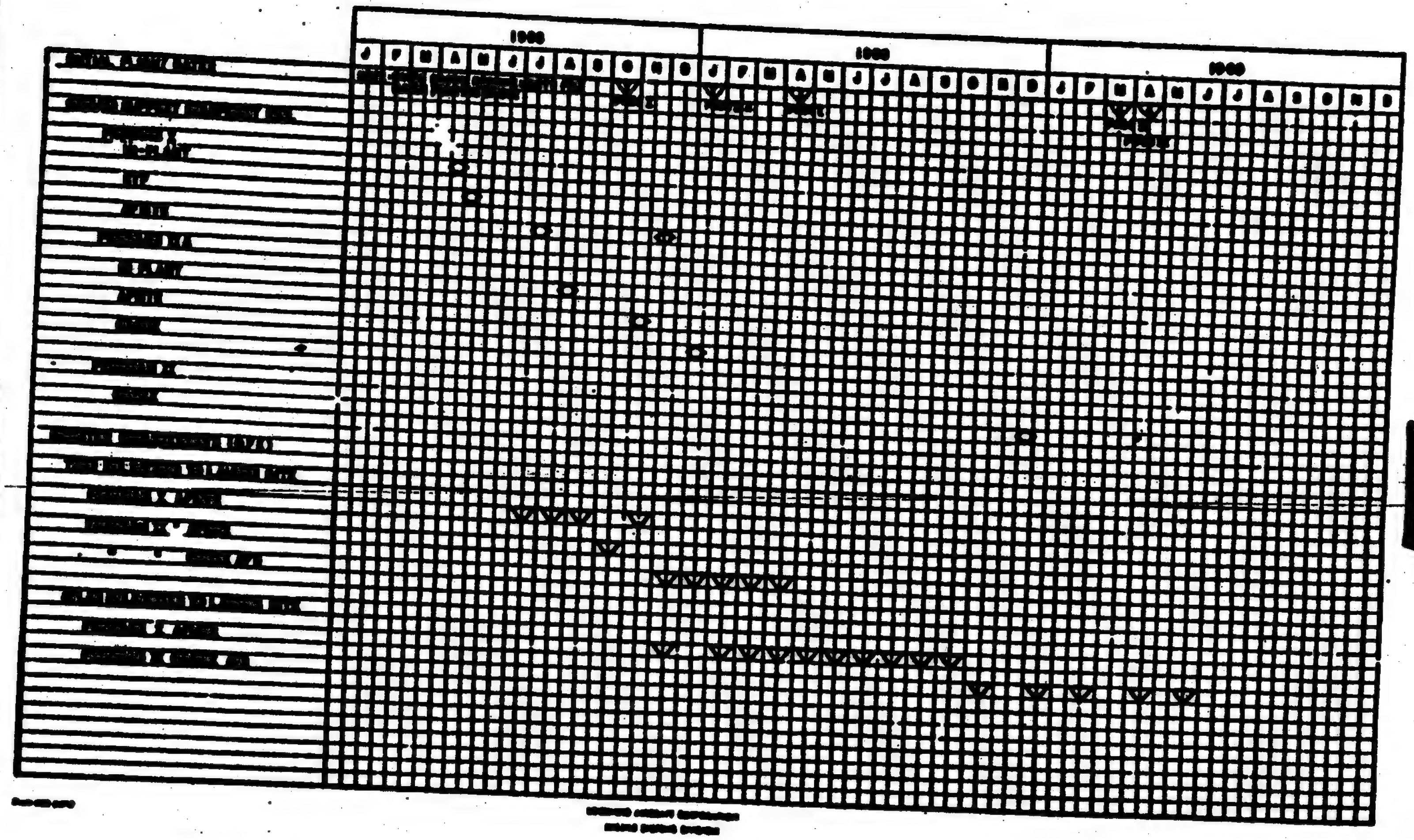

WS-117L Milestones Accelerated Program, Ground Support Equipment and GFE Requirements

SECTION 4

TECHNICAL ANALYSIS

4.1 Performance of the WS-315A, Series IV and WS-107, SM-65 Vehicles as Boosters for WS-117L

The acceleration of the WS-117L program is based on the use of the WS-315A, series IV vehicle (Thor) as a booster for a second stage which goes on orbit. The weight breakdown used for the Thor is shown in Table 4-1, and the performance assumed for this booster is shown in Figure 4-1. This figure also furnishes the data which permits calculation of the amount of weight which can be placed on orbit for various values of second stage specific impulse. The results of these orbiting weight calculations are shown in Figure 4-2.

The present vehicle of the WS-117L program was designed to use the Atlas SM-65D vehicle as a booster. Its design was predicated on the use of an engine having an early availability, as well as having a gross weight and configuration compatible with Atlas capabilities. The weight of reconnaissance payload which can be put on orbit, using rubberized versions of the WS-117L vehicle design, are shown in Figure 4-3. The negligible penalty paid in terms of payload on orbit caused by using this already designed airframe, guidance, and propulsion system of the present WS-117L vehicle instead of redesigning to achieve the optimum vehicle is also shown in Figure 1.2.

It is obvious from Figure 4-2 that an increased specific impulse will give increased capability, however, achieving this increased capability will require an increased engine development time. The feasibility of including these developments as a later program improvement appears desirable in terms of the relative cost and value of the increased payload.

Finally the amount of reconnaissance payload, using the WS-117L vehicle as a function of orbit altitude is shown in Figure 4-3.

The performance of the presently designed WS-117L vehicle when used with the SM-65-D as a booster is also shown in Figure 4-3. The design of this vehicle has been determined by the structural strength

TABLE 4-1

WEIGHT SUMMARY

THOR SERIES - IV BOOSTER

The booster stage consists of the Thor Series IV missile less the Re-Entry body. The Thor weight breakdown obtained from AFBMD is presented below.

Structure		3045
Guidance Section	390	
Fuel Tank	712	
Lox Tank	884	
Center Section	108	
Engine Section	550	
Thrust and Launch Struct.	196	
Exterior Finish	14	
Tunnels	111	
Fins	80	
Propulsion Group		2382
Engine Instl.	1839	
Starting System	7	
Propellant System	536	
Guidance and Control Group		1712
Guidance Units (ACSP)	1036	
Electrical Controls	204	
Hydraulics	178	
Vernier Motors and Tanks	131	
Vernier Press. System	163	
Range Safety		50
Separation System		62
Electrical System		442
Booster Dry Weight		7693
Unusable Liquids		1545
Propellant in Motor	305	
Propellant in Piping	224	
Propellant in Tanks	976	
Propellant in Verniers	20	
Unusable Oil	20	
Pressurization Gas		429
Vernier Burnout Weight		9667
Vernier Propellants		49
Main Stage Burnout Weight		9716
Liquids Burned		96752
Fuel	30035	
Lox	66605	
Lube Oil	112	
Booster Lift-Off Weight		106468

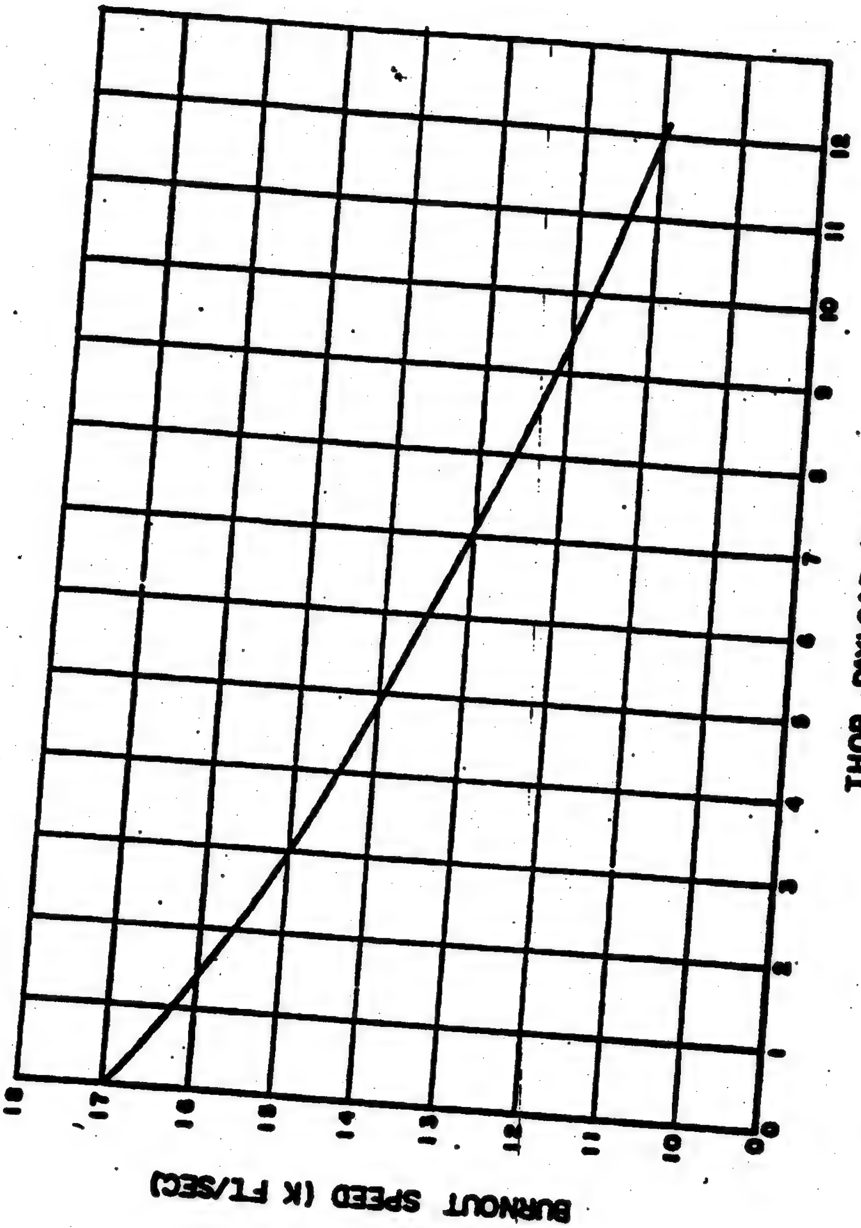

Fig. 4-1 Thor Performance (Speed at Burnout vs Payload)

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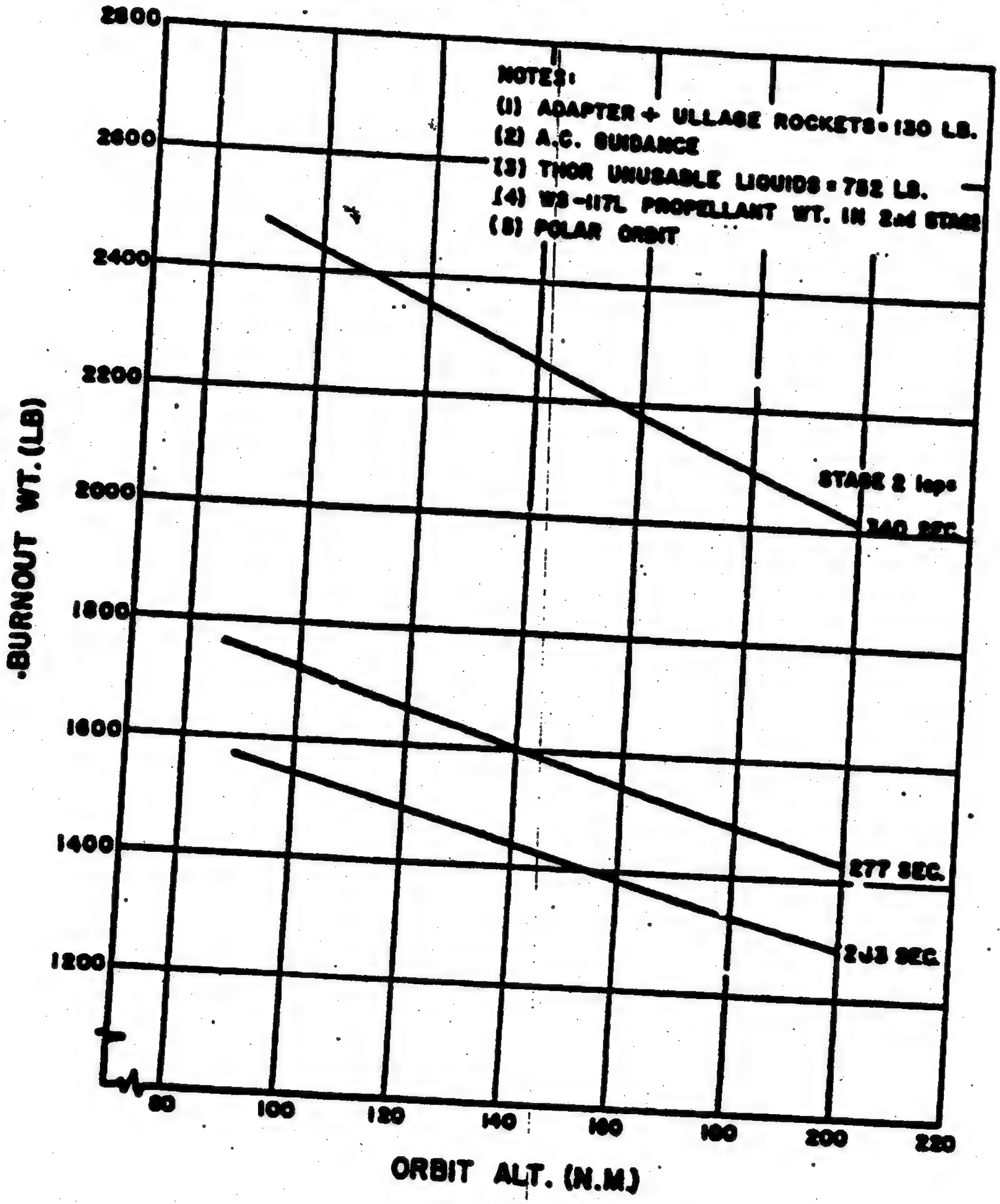

Fig. 4-2 BURNOUT WT. ON ORBIT VS. ORBIT ALTITUDE AS FUNCTION OF SECOND STAGE Isp

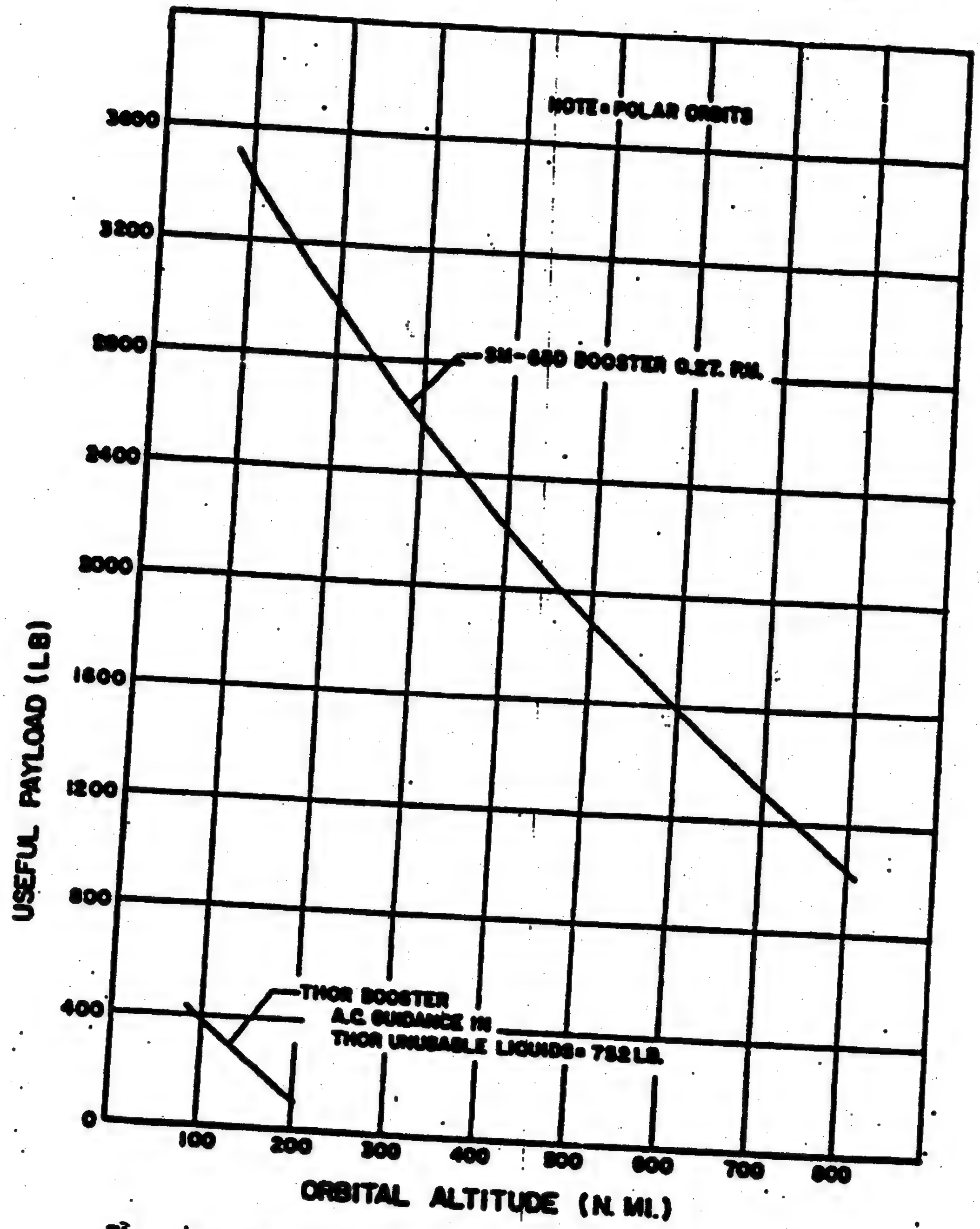

Fig. 4-3 Useful Payload vs Orbit Alt. (WS-117L with Thor & Atlas Boosters)

[redacted]

of the SM-65D vehicle. For a specific impulse of 263 sec in the final stage the payload is very little less than that which could be achieved with a strong booster. It appears, however, that program improvement would require an increased structural capability in the SM-65 vehicles to achieve the maximum benefit from an increased specific impulse engine in the WS-117L vehicle.

4.2 Preliminary Design of the Vehicle

The WS-117L vehicle has been designed for use on the SM-65D vehicle. This design followed extensive analysis. These analyses covered the required margins of performance, the minimum weight compatible with structural integrity in terms of the geometry required to achieve adequate guidance in ascent and stability on orbit. They also covered the properties of the chosen materials in terms of the expected environment. These analyses also covered the design of the maximum performance propulsion system using an engine of early availability, selection, and adaptation of the best guidance system having this same early availability, and finally, designing the airborne system to achieve the best total system performance in terms of satisfying the requirements of satellite reconnaissance.

The size and weight of the vehicle were optimized under the constraints imposed by the structural capabilities of the WS-107, SM-65, vehicles, the expected environment, and the conditions at launching as well as during boost.

The WS-117L vehicle, as designed for the Pioneer Visual System, was modified to furnish data for the analysis, reported in Appendix A, covering the performance of the WS-315A, Series IV, (Thor) vehicle used as a booster. This analysis showed that the same vehicle with reduced payload very nearly met the conditions of optimum design when used with the Thor booster.

For this reason the WS-117L vehicle was chosen as the second stage of a two stage system to achieve orbital conditions with the Thor booster used as a first stage.

The modifications of the vehicle dictated by this use are listed below.

a. Revision of the aft structure to eliminate the mechanism for orbital stability achievement.

b. Revision of the nose structure to accommodate the Rand Reconnaissance package and furnish spin-up and separation of the package.

c. Remove the Pioneer Visual Reconnaissance equipment and its supporting structure.

The weight breakdown of the WS-117L as modified is given in Table 4-2. That of the Thor is given in Table 4-1.

A new adapter was designed to mate the WS-117L vehicle with the Thor. This connects the forward end of the present Thor adapter to the present adapter ring on the WS-117L vehicle. Analysis indicates that the existing Thor adapter may need stiffening and that the Thor separation retrograde rockets may need repositioning. These were determined to be minor changes, however.

The general arrangement of the redesigned WS-117L vehicle, and the Thor booster are shown in Figures 4-4. An early preliminary design of one possible version of the Recoverable Reconnaissance package is shown in Figure 4-5..

Separation at the end of Thor boost will be achieved with a simple modification of the present separation system.

Spin-up and separation of the Recoverable Reconnaissance package is achieved by using tangent thrust solid propellant rockets to achieve the required spin-rate, after which separation is achieved through the use of a loaded spring. This operation requires a separation energy of about 8 ft-lbs. The total rocket impulse required to spin up the package is about 8 lb sec. It is believed that the most precise method of separating at the desired spin rate will be optical, however, further investigation is required to determine the accuracy and reliability of this system, and assure its advantages over other systems.

[redacted]

TABLE 4-1

WEIGHT SUMMARY

WS117L MODIFIED FOR RECOVERABLE PAYLOAD

Structure		330
Nose Cone	28	
Forward Body	102	
Mid Body	51	
Aft Equipment Support	30	
Adapter	104	
Misc. Attachments	15	
Destruct Charge and Arming Mechanism		25
Propulsion Group		599
Bell Engine Instl.	265	
Propellant Tank Instl.	229	
Ullage Control Rocket Instl.	30	
Pressurization System	75	
Controls		138
Hydraulic Actuator System	47	
Attitude and Roll Control System	68	
Flight Control Electronics	23	
Auxiliary Power Supply		38
Guidance		80
Spin System and Separation		30
Monitor Panel		16
Recoverable Payload		300
Heat Sink	91	
Camera	42	
Attitude Sensor	5	
Container	20	
Battery and Motor	13	
Rocket Case	9	
Propellant	51	
Tracking Beacon	16	
Recovery Beacon	9	
Light	4	
Dye Marker	5	
Structure	35	
Weight Empty		1556
Propellants		5894
Expendable	5835	
Residual	59	
Booster Payload		7450
Burnout Weight		1482

SATELLITE VEHICLE GENERAL ARRANGEMENT

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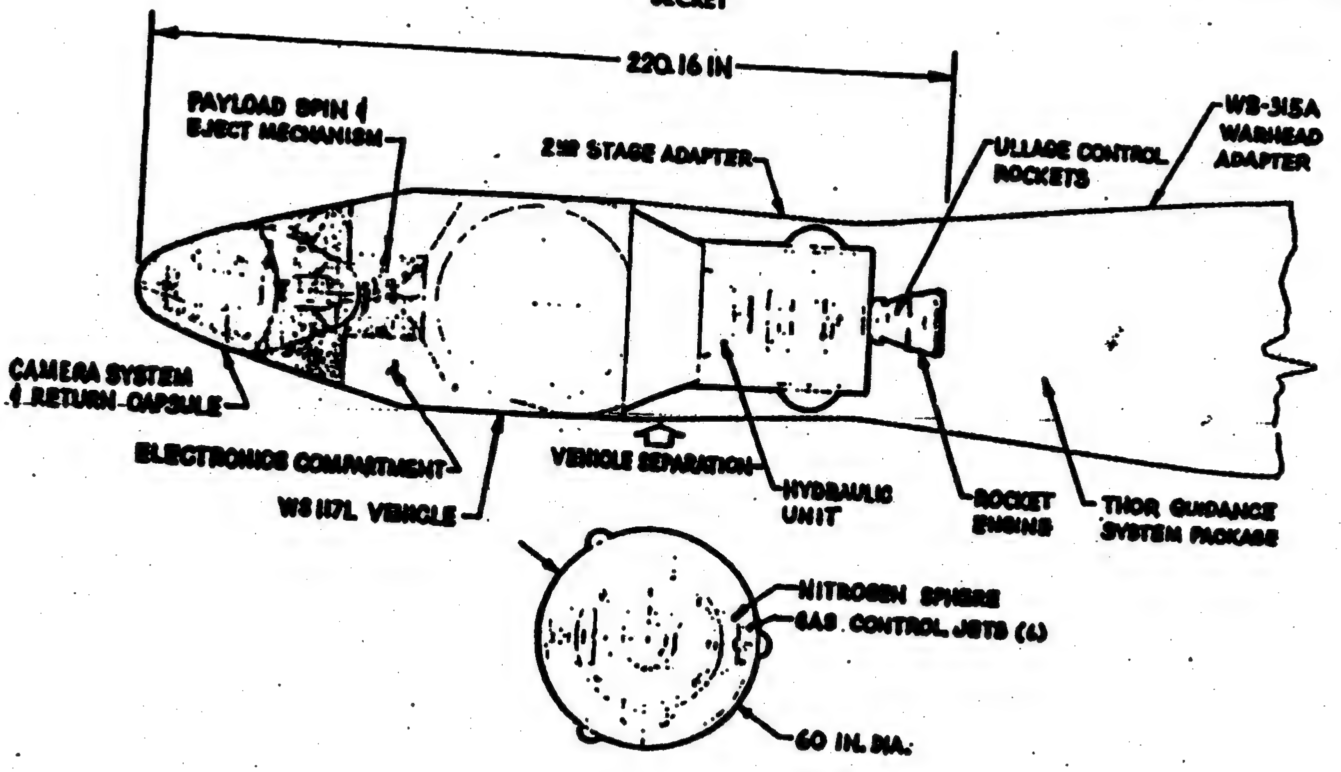

Fig. 4-4

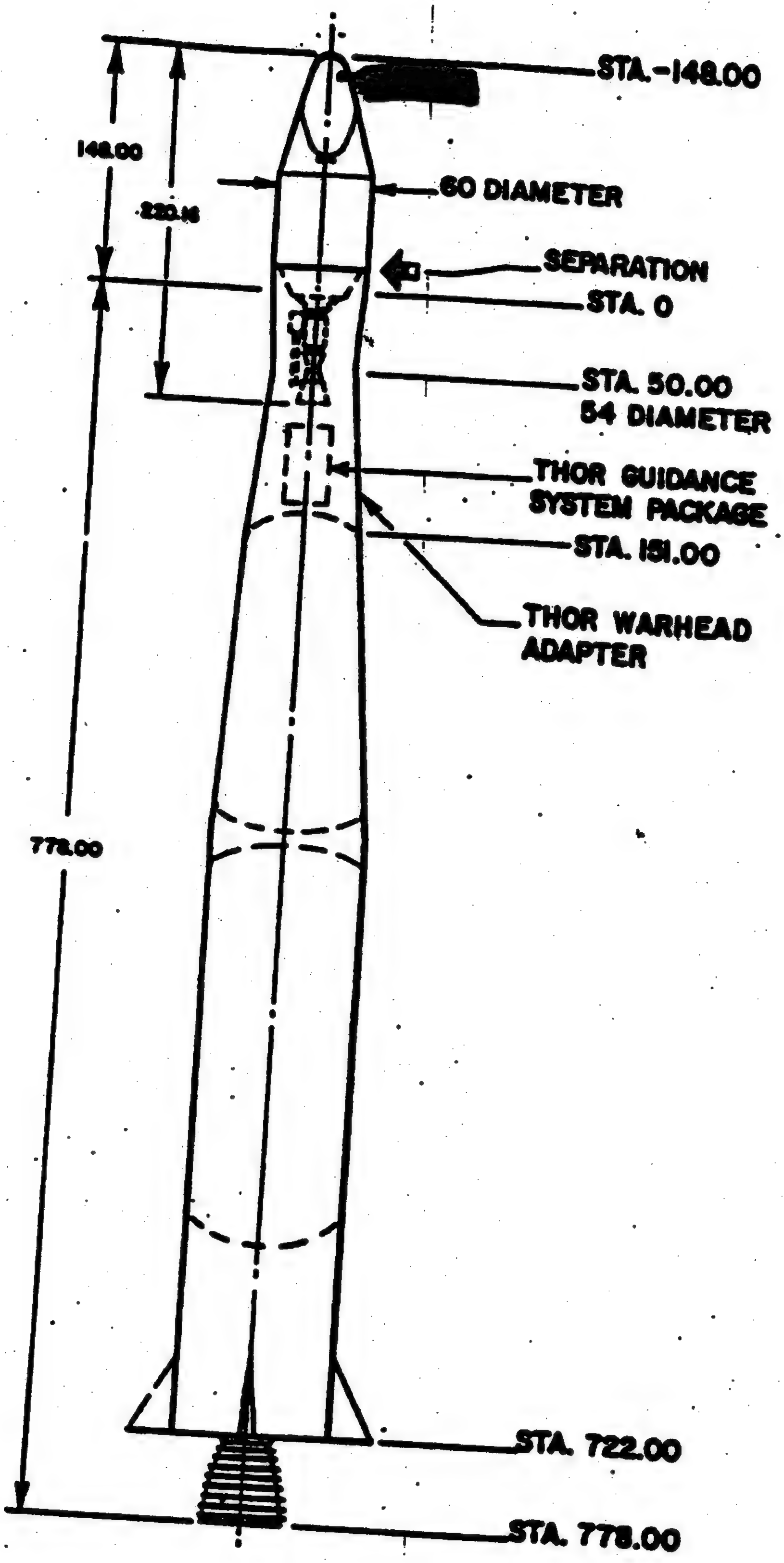

Fig. 4-4a Booster-Satellite Vehicle Arrangement

RECOVERABLE PAYLOAD INSTALLATION

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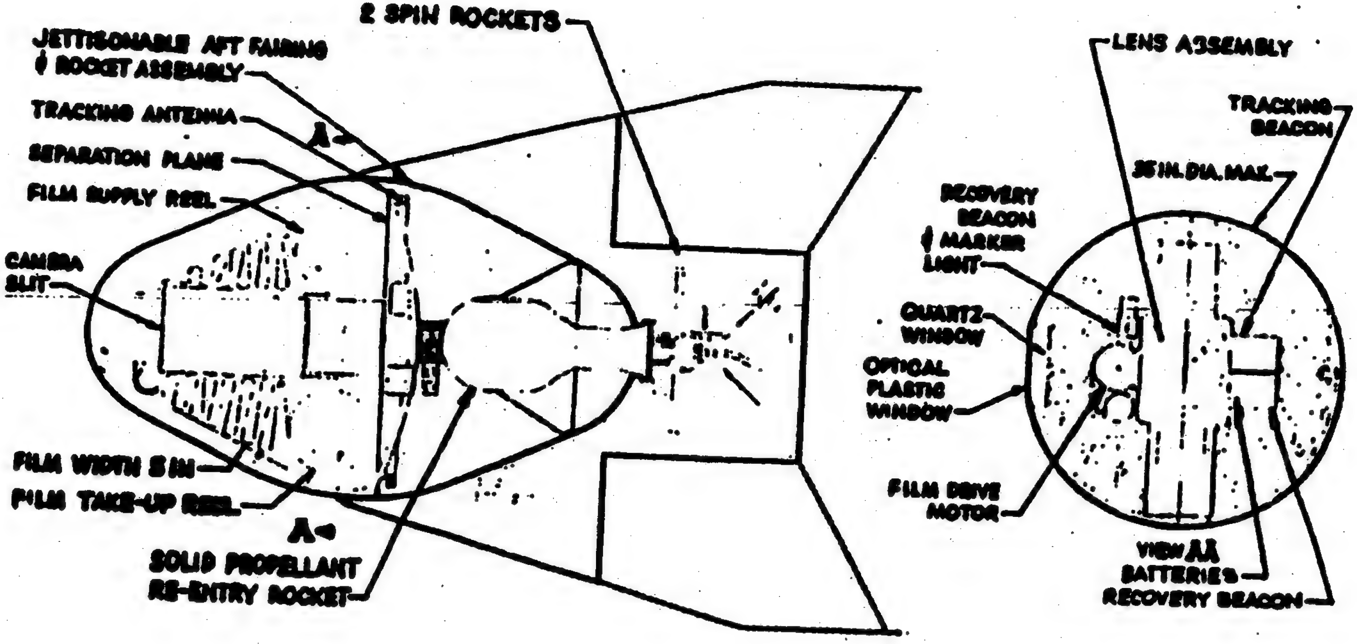


Fig. 4-5

4.2.1 Redesign of the Rand Package and Heat-Shield Estimates

The Rand estimates of the heat shield requirements have been examined. Assuming the body to be sufficiently stable to orient itself to a nose-first attitude upon reentry and to maintain this orientation during the trajectory, the Rand estimate of 65 pounds of ablative material for heat shielding has been verified. However, analysis indicates that the Rand configuration is marginally stable which leads to a revised estimate of the required ablative heat shield weight to about 195 pounds, increasing the total weight of the orbiting system to about 440 pounds, and the reentry weight to 385 pounds.

A preliminary re-design of the reentering shape has been made. Satisfactory entry can be achieved with the same forward section and a slightly bulged aft section. This capsule contains approximately 135 pounds of equipment (data record, camera, structure, recovery equipment). Application of the method of Eggers in NACA Technical Notes, to the resulting configuration establishes the total heat input to the body surface during the reentry as approximately 2.015 x 10 ft-lb, or 25,900 BTU.

The use of the same design factor used in the Rand analysis for the weight required for ablative heat shield gives a requirement for 66 pounds on the forward surface of the capsule. An additional 25 pounds will absorb the heat transferred to the aft portion of the body, during the period when the aerodynamic loads may not be sufficient to properly orient the body. It presently appears desirable that the ablative material for this system be a fiberglass-plastic layer on top of a 0.050 inch MG-alloy shell, backed by foam plastic filler to give the required structural strength. The density of the ablative fiberglass-plastic will be about 110 lb/ft^3 or 0.0672 lb/in^3 for design purposes.

To achieve the desired reentry weight it appears desirable to jettison the batteries used on orbit and the wind shield which maintains symmetry of shape on orbit at initiation of the firing of the solid propellant, reentry impulse, rocket. At burnout of this rocket its empty case is jettisoned, possibly along with the camera equipment. The film, stored in a strong container, and the equipment required to effect recovery, will be in the reentry body.

4.3 Operations Analysis

4.3.1 Orbit Implications

Figure 4-6 illustrates the photographic ground coverage that is theoretically attainable with the proposed camera vehicle on a circular polar orbit at a constant 135 miles altitude. Overlap extends northward from 46 degrees North latitude, giving efficient coverage of the zone of interest in four days.

On Figure 4-7, the drag life curve for 135 miles altitude indicates that the loss in altitude at the end of the fourth day will be 13.6 miles.

Figure 4-8 illustrates the coverage for constant altitudes of 140 and 145 miles for five and six days respectively at 40 degrees North latitude. Additional overlap is realized only at the increased cost of greater altitude and longer working time.

4.3.2 Tracking and Recovery Station

For vehicle photographic orientation at 55 degrees North latitude over the Soviet, the optimum point at which to initiate the recovery will be about 65 degrees North latitude in Alaska. An estimated requirement of two minutes tracking time for trajectory computation and impact prediction does not introduce a complication since the retro thrust angle can be allowed to vary between 100 degrees and 140 degrees.

For the tracking function alone, in the case of self-initiation of the retro-thrust, near-polar locations are obviously best. Thus, an Alaskan station location is optimum for both tracking and recovery. Additionally, an Alaskan station will provide first-pass tracking following an IOC launch.

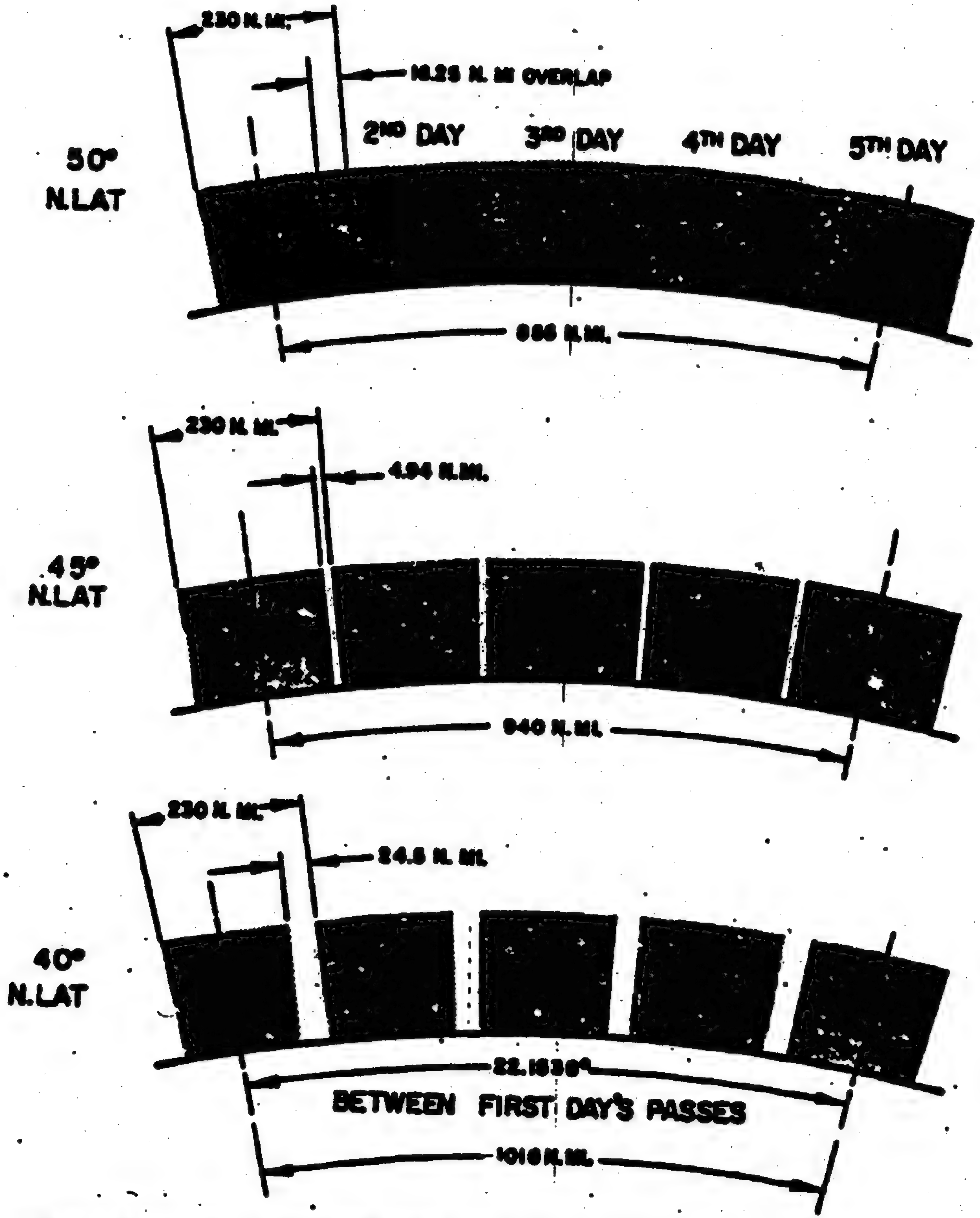
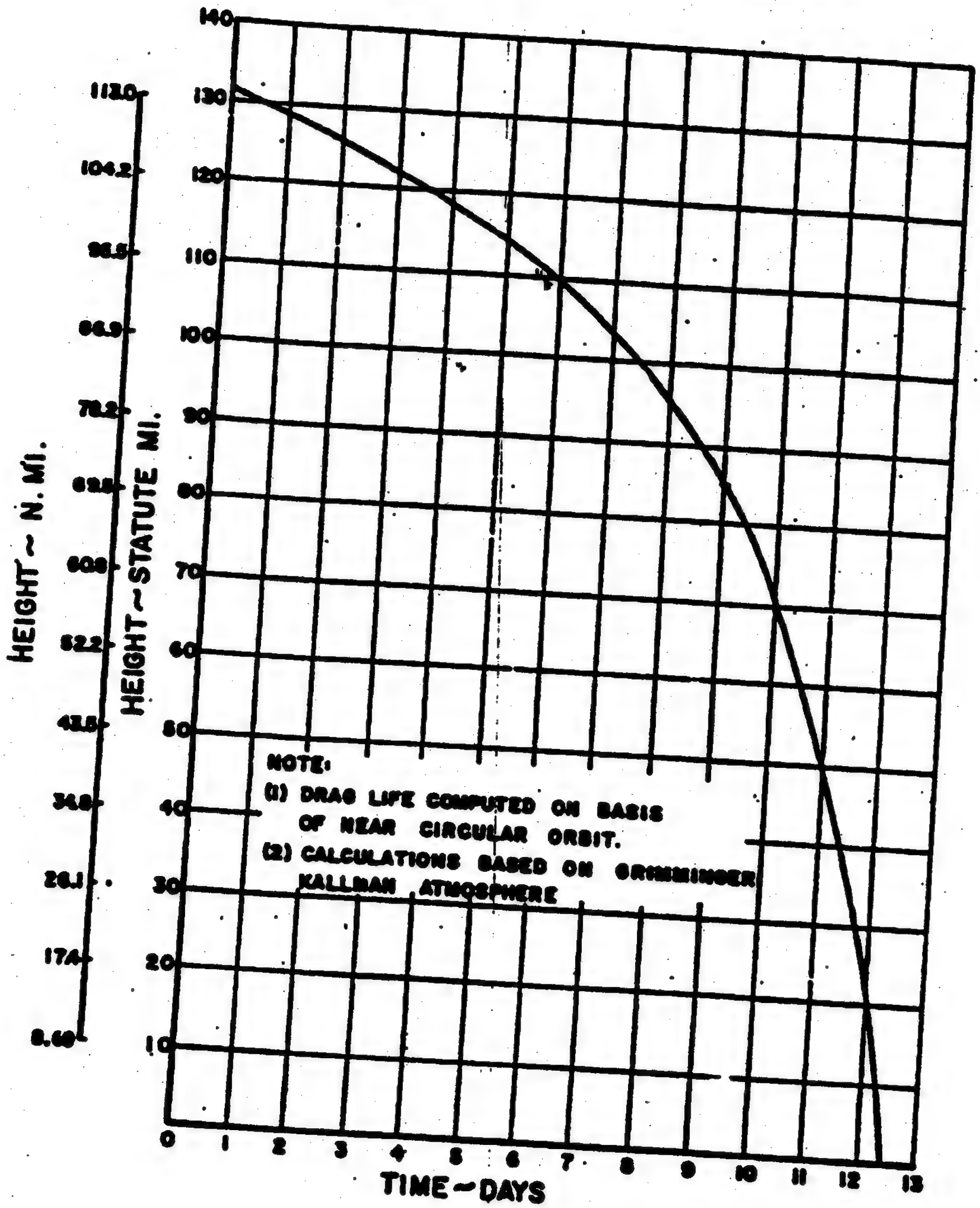


FIG. A-6 FOUR DAY COVERAGE AT 115 N. MI. ALTITUDE AT THE LOWER LATITUDE OF INTEREST. EXACT COVERAGE IS OBTAINED AT 46°-10' N. LAT.



NOTE:
(1) DRAG LIFE COMPUTED ON BASIS OF NEAR CIRCULAR ORBIT.
(2) CALCULATIONS BASED ON GRIMMINGER KALLMAN ATMOSPHERE

FIG. 4-[illegible] DRAG LIFE CURVE FOR A VEHICLE WEIGHING 300 LBS, AND WHOSE AVERAGE DRAG COEFFICIENT DURING FLIGHT IS 2.42.

[redacted]

4

[redacted]

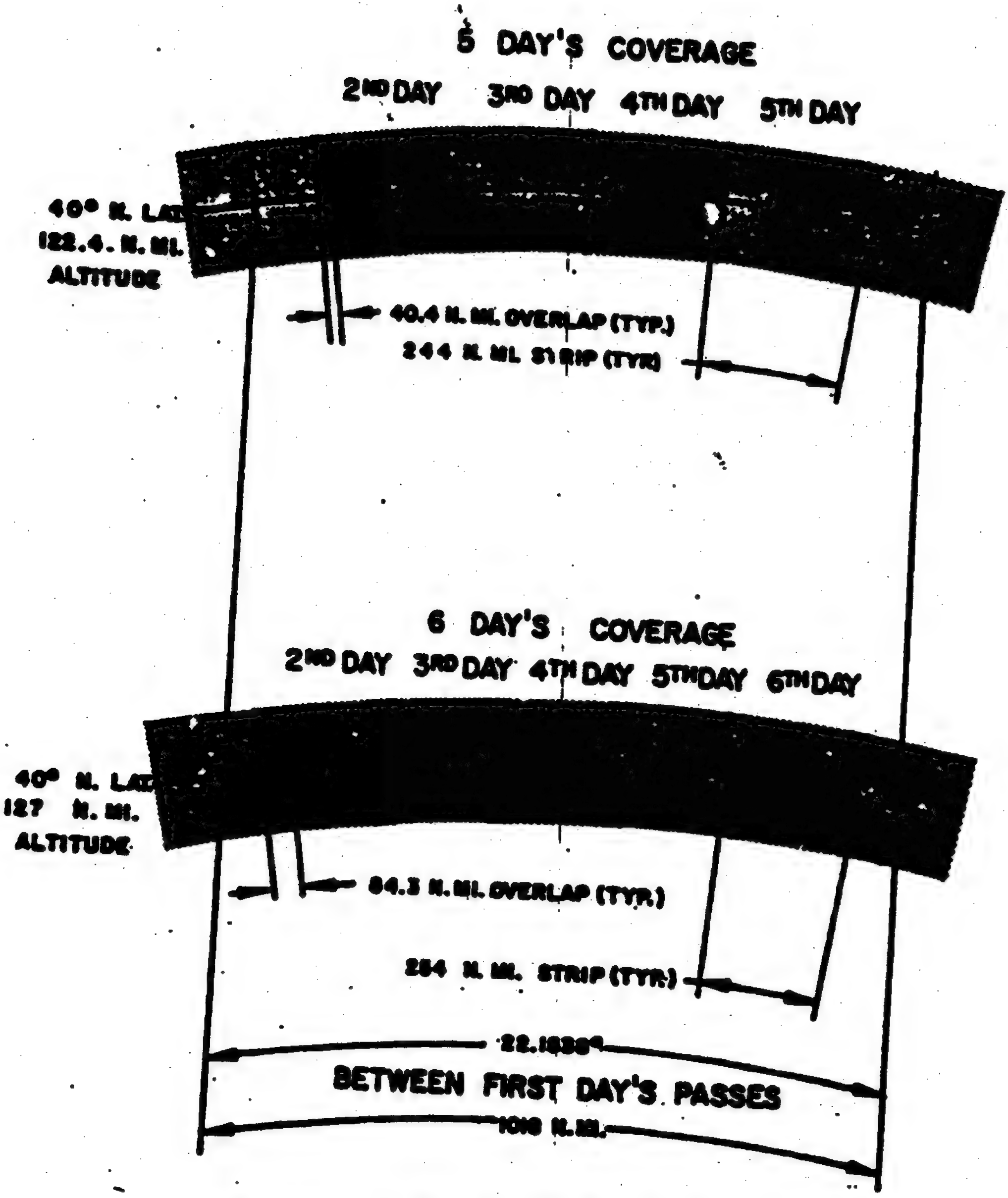


Fig. 4-8 Coverage for 140 and 145 Mi. Altitude at 40° North Latitude

4.3.3 Probable Search Area

The impact area search problem is a matter of matching the vehicle's beacon range to the probable impact prediction error. This error includes not only that of the tracking, but also involves those of retro angle and impulse, and unpredictable atmospheric variations.

Present estimates suggest the following standard deviations in prediction accuracy with respect to the error sources:

Tracking = 10 n mi radial
Retro angle = 5 n mi radial
Retro impulse = 20 n mi radial
Atmospheric variation = 5 n mi radial

With a circular probable error at impact of less than 30 nautical miles a beacon range of 50 nautical miles on the vehicle appears to be the correct order of magnitude.

4.3.4 Optimum Retro-Thrust Angle

The spin axis of the photographic vehicle is required to be parallel to the local horizontal at the optimum latitude of interest. If the latter is chosen as 55 degrees North latitude over the Soviet, at 65 degrees North latitude over Alaska, the retro-thrust vector will be directed 30 degrees rearward of the local vertical or 120 degrees to the vehicle's velocity vector. This is close to the optimum retro-thrust angle for a vacuum recovery of the vehicle.

A variation in retro-thrust angle that may be indicated by the thermo-dynamics of the reentry into the atmosphere can be accomplished by varying the latitude of the retro ignition.

4.3.5 Reentry Trajectories

The order of magnitude of the ground distance of the vacuum recovery trajectory can be judged from Figure 4-9, which illustrates the computation in RAND Report No. RM 2012 for a 155 mile altitude.

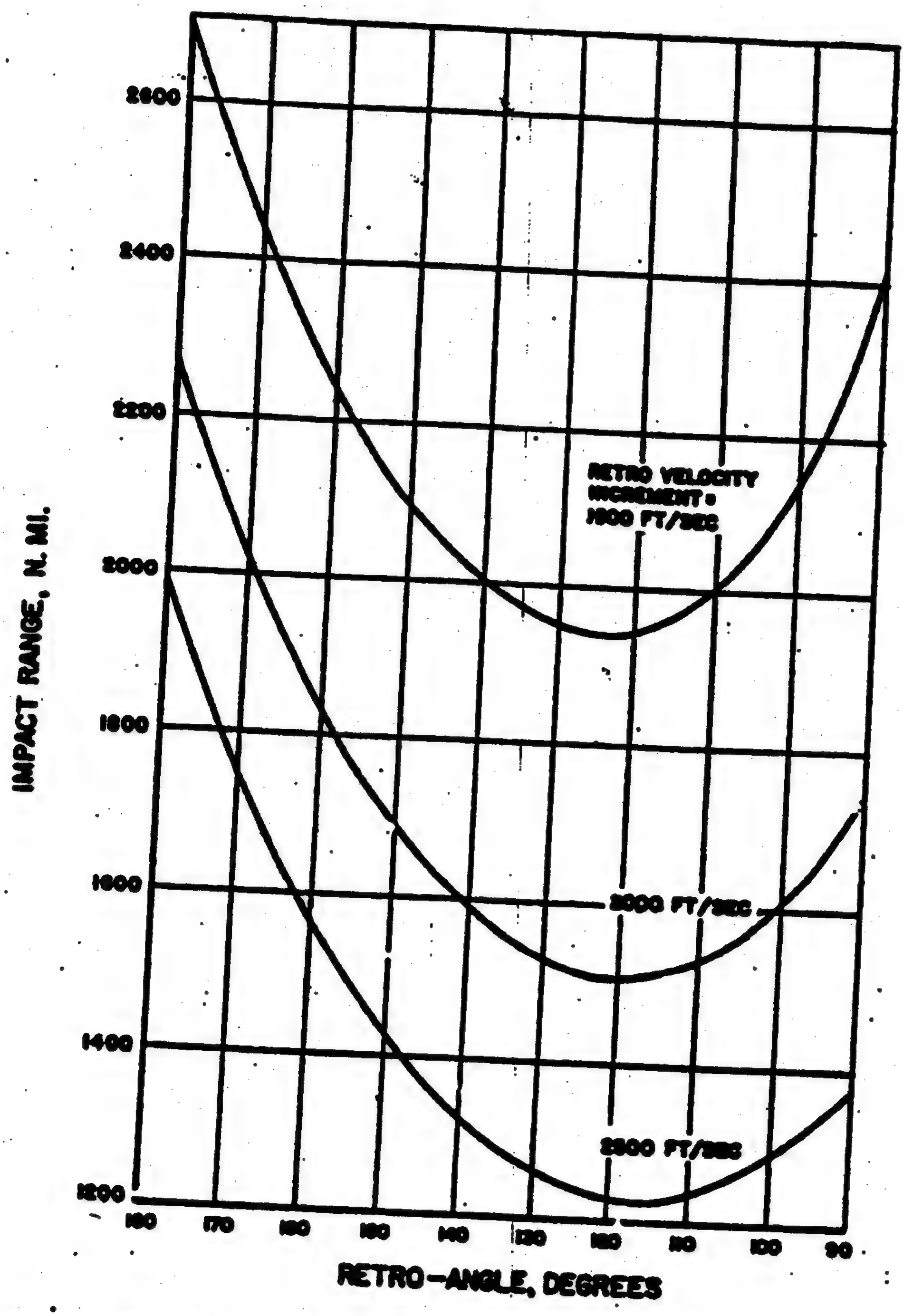


FIG. 4-9 VACUUM DESCENT RANGE AS A FUNCTION OF MAGNITUDE AND RETRO-ANGLE OF VELOCITY INCREMENT

Figure 4-10 shows the impact ranges for several altitudes, retro velocity increments and retro angles, in a realistic atmosphere. A stable reentry is assumed (no supersonic lift).

It will be noted that a variation of 100 ft/sec in retro velocity will vary the impact range 100 nautical miles; a variation of 15 degrees from the optimum retro angle produces only a small variation in the impact range. Figure 4-11 shows the effect on impact range of varying the ratio of form drag to mass for 155 mile orbits.

Calculations of impact ranges based on the atmospheric model used in Figure 4-10 must reflect standard deviations of 2 nautical miles due to winter winds and of 3 nautical miles due to variations in atmospheric density in the trajectory direction.

4.4 Choice of Camera Parameters

A typical day of operation will give a vehicle path over Russia and Siberia with a total length of 7,200 nautical miles. When the areas of China and the Satellite nations are included, however, a day of operation may give a path length as long as 9.5×10^3 nautical miles. For the lens, camera, and film of reference 1, as well as the present considerations of Fairchild, the ground resolution is 60 feet for the film resolution of 40 lines per millimeter. The above path length of 9.5×10^3 nautical miles, or 5.7×10^7 feet, corresponds to 9.5×10^5 units of resolution on the ground. This many units of resolution on the film is contained in a length of about 2.4×10^3 cm.; or 80 feet. Since the film is used to cover a strip normal to the path, the width of all of the strips should add to this 80 feet. The overlap along the flight path between successive strips should be about 25%, thus the total of the strip widths should be about 100 feet. To give the optimum coverage the strip of picture should have a length of about five times its width; thus the total roll of film should have a length of about 500 feet for one day of operation.

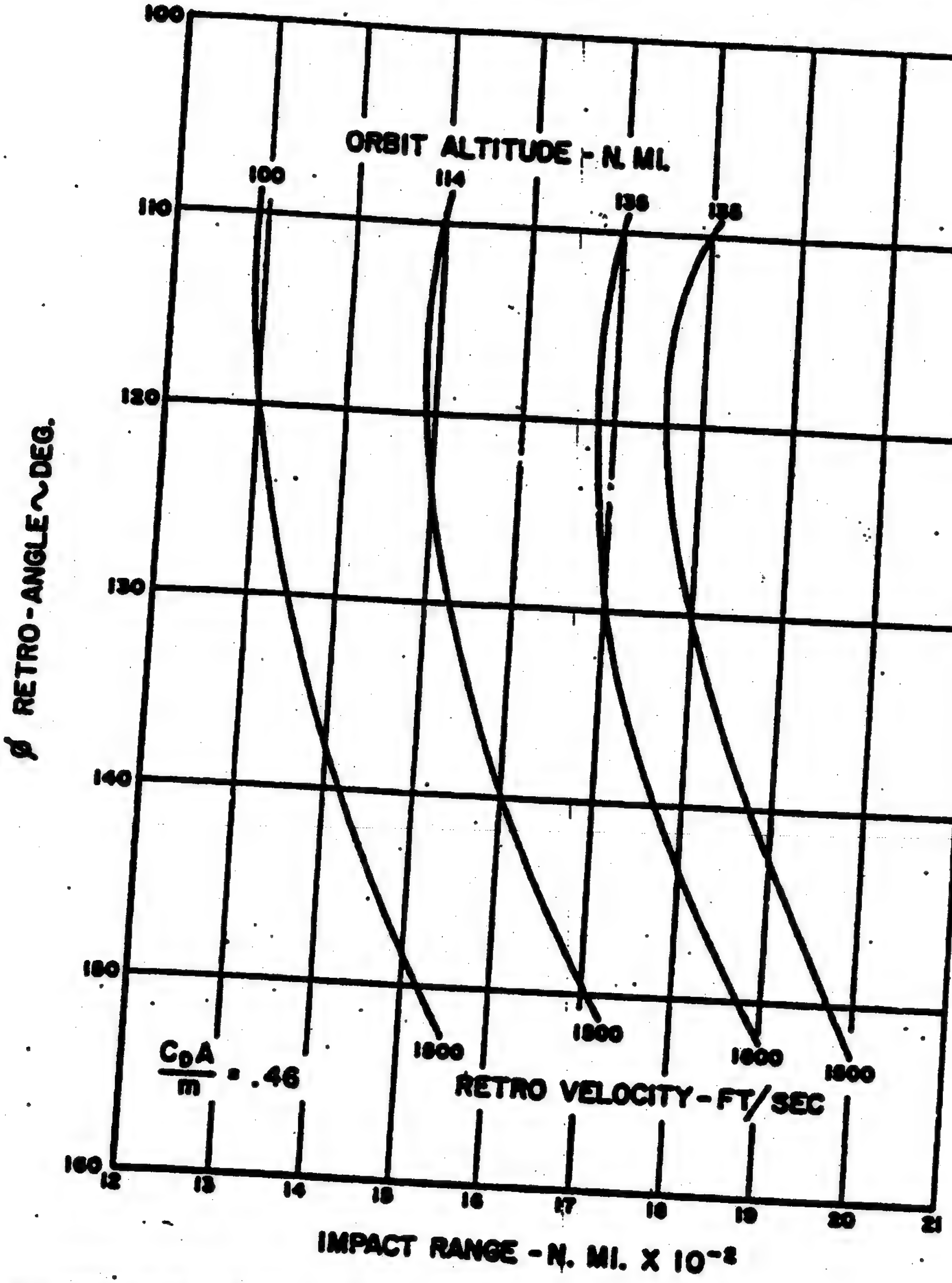


FIG. 4-10 RETRO-ANGLE VS IMPACT RANGE FOR VARIOUS ORBIT ALTITUDES AND RETRO VELOCITIES

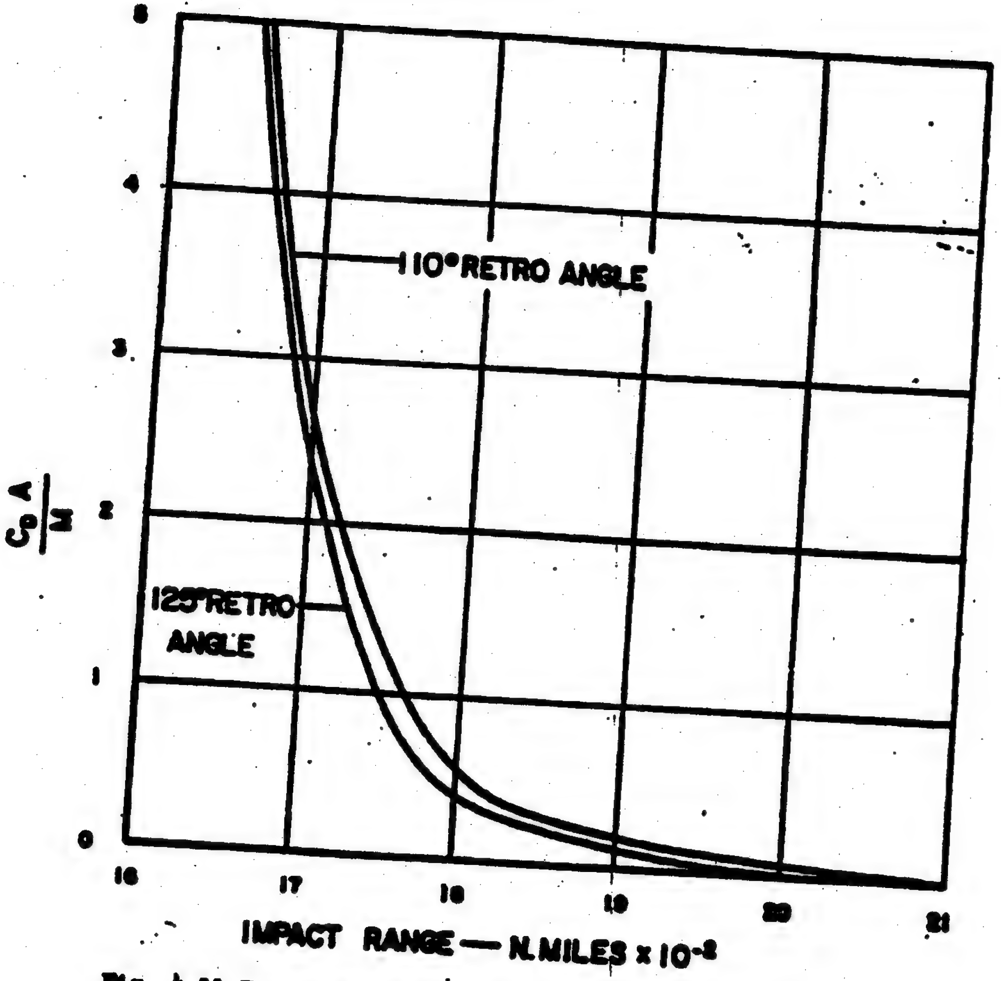


Fig. 4-11 Effect of $\frac{C_D A}{M}$ on Impact Range

The picture width on the film is 4.5 inches and the film has a resolution of 40 lines/mm. The picture width corresponds to 4580 units of resolution. If each of these corresponds to 60 feet on the ground, the picture covers 45.8 nautical miles. The centers of the pictures should be 36.6 nautical miles apart to allow 25 per cent overlap between adjacent pictures. The ground speed of the vehicle is nearly 4.0 nautical miles per second, so the pictures should be taken at intervals of about 9.2 seconds. Thus the spin frequency should be some multiple, n, of 6.51 revolutions per minute. There will be n-1 revolutions between the exposure sweeps. The proper choice of n will depend on the combination of film speed, exposure time and slit width as well as the design of the image motion compensation device, with due consideration being given to the possible elimination of the image motion parallel to the exposure slit, the proper variation of film speed during the sweep and the effects of these on the stability of the vehicle in orbit.

The choices made in reference 1, which will be changed only if further study shows that they cause a sever penalty, permits an exposure time of 0.00025 second, a value of $n \cong 3$, an actual spin rate of 18.2 revolutions per minute. This latter gives 39.5 miles between exposures, or about 16 per cent overlap between adjacent exposures.

Locational degradation due to perturbations in the direction of the spin axis can be kept to a minimum by proper relations between the principal moments of inertia to reduce gravitational variation, and symmetry of vehicle shape to reduce aerodynamic variations.

4.5 Recoverable Reconnaissance Package Orbital Stabilization

The package on a polar orbit, rotating about its axis of symmetry, will try to maintain its orientation in space. Due to the oblateness of the earth it will be subjected to a periodic gravitational torque having period equal to one-half of the orbital period.

This torque will give rise to a (small) periodic yaw motion of amplitude $a = \frac{3}{4} \frac{C - A}{A} \frac{\omega}{N}$ where A, C are respectively the moments of inertia about the axis of symmetry and about any perpendicular axis through the mass center, N is the rotational angular velocity and ω the orbital angular velocity.

When the package is in a slightly yawed position the same effect gives rise to an additional small gravitational torque component, which will cause a displacement in pitch. Thus at the end of a single orbital period the pitch orientation of the vehicle has changed downward by an amount (in radians):

$$\Delta P = 2\pi \; (2a\,Y_o - 3a^2),$$

where Y_o is the yaw angle to the left (in radians, of course) at the beginning of the period. The corresponding secular change in yaw itself is:

$$\Delta Y = 2\pi \left\{ \frac{3}{2} \epsilon^2 a \sin (2L_o - 2L_p) - \frac{1}{2} J \left(\frac{R}{\ell}\right)^2 a \sin 2L_o + 2a^2 Y_o P_o \right.$$

$$\left. - 8 \epsilon a^2 Y_o \sin (L_o - L_p) \right\}$$

where ϵ is the eccentricity of the polar orbit, ℓ is its semi-latus-rectum, R the earth's mean radius, $J = 1.637 \times 10^{-3}$ (oblateness coefficient), L_o the initial latitude, L_p the perigee latitude.

If

$$\frac{2\pi}{\omega} = 90 \text{ minutes}, \; \frac{2\pi}{N} = \frac{1}{18} \text{ minutes}, \; \frac{C}{A} = 2 \text{ minutes}$$

then $a = 4.6 \times 10^{-4}$ rad., giving rise to a secular change in pitch, in case $Y_o = 1$ degree, of amount $\Delta P = .09$ degrees per day. The secular change in yaw is much smaller unless the eccentricity ϵ is considerably greater than .01; which is about the maximum eccentricity at which an orbit will be established.

4.6 Recoverable Package Re-entry Requirements

An examination of the re-entry requirements for the conditions reported in Reference 1, show that the Rand requirements for weight of ablating material are satisfactory if the body shape is assumed to be very stable. However, stability analyses showed that the oscillations of the angle of attack were not damped appreciably and that the weight required for heat shield should be larger by nearly a factor of 3.

Further analyses, shown below, showed that a stable configuration, with very nearly the shape of the forward section shown by RAND, could be used for re-entry with low requirements on weight of heat shield. This was determined by varying the results obtained for a spherical body by using results obtained in the X-17 program. These analyses also indicated that a lighter re-entry could be used with considerable saving in the total weight of the reconnaissance package. The total weight used will depend on the complete camera design and the duration of reconnaissance required. Further study is required to determine the best design of the re-entry package, this will be done after determining the camera design, selecting the recovery equipment and completing the analysis of the orbiting vehicle stability.

4.6.1 Heat Transfer Analysis

To begin the heat transfer analysis of a body entering the atmosphere from a satellite orbit, one must determine whether or not there is a possibility of experiencing turbulent heat transfer. Since the re-entry trajectories are very shallow and decelleration to low velocities occurs high in the atmosphere, laminar flow will predominate during the span of sensible heating.

To verify this, the momentum thickness Reynolds number, R_{e_θ}, at the sonic point on a 2 foot diameter sphere was computed for various entrance angles and drag-mass parameters. The results are shown in Fig. 4-11a, and the values of R_{e_θ} presented correspond to those at the end of the heating angle, assuming a surface temperature of 2200°F. Maximum values of R_{e_θ} differ from those shown by 4 percent at most.

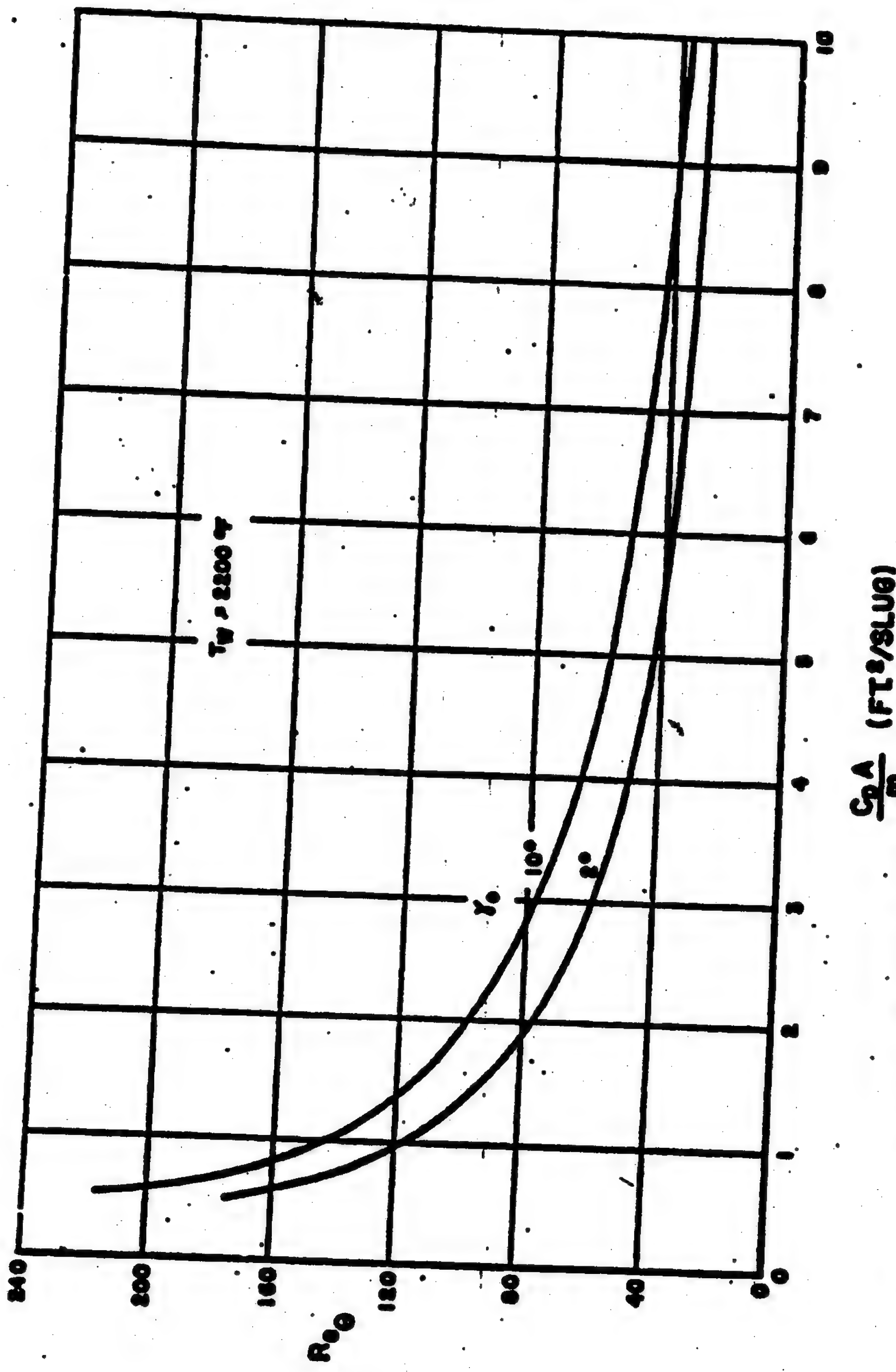


Fig. 4-11a Momentum Thickness Reynolds Number at End of Heating

Experience gained on the Lockheed X-17 Re-Entry Test Vehicle program has shown that R_{e_θ} must exceed about 250 in order for transition from laminar to turbulent flow to occur. Since the maximum value of R_{e_θ} to be expected on satellite re-entry trajectories is about 200 occur very near the end of heating, it can be safely concluded that the flow will be laminar during virtually the entire span of heating.

There is a possibility of obtaining a limited amount of turbulent flow just before heating ceases, but even in this case the Reynolds numbers will be so low that turbulent heat rates will be approximately the same as laminar values. Figure 4-12 compares predicted laminar stagnation point heat rates and the peak turbulent heat rates on a 2 foot diameter sphere with a drag-mass parameter of 1 for an entrance angle of 4 degrees. Note that predicted turbulent heat rates are substantially lower than laminar values until near the end of heating.

Assuming that the boundary layer will remain laminar throughout most of the heating cycle, the Fay-Riddell Theory, (Reference 1) for an equilibrium dissociated boundary layer with Lewis number 1.4 and Prandtl number 0.71, gives the stagnation point heat rate as:

$$q_0 = \frac{C_0}{\sqrt{R_n}} \sqrt{\rho/\rho_{sc}} \; U^{3.25} \left(1 - \frac{h_{gw}}{h_{se}}\right) \quad \text{BTU/ft}^2\text{-sec} \qquad (1)$$

where

$C_0 = .95 \times 10^{-10}$

R_n = nose radius of curvature at stagnation point, (ft)

ρ/ρ_{sc} = ratio of ambient to sea-level density

U = flight velocity (ft/sec)

h_{gw} = total enthalpy of gas at wall, (BTU/lb)

h_{se} = total enthalpy of flow, (BTU/lb)

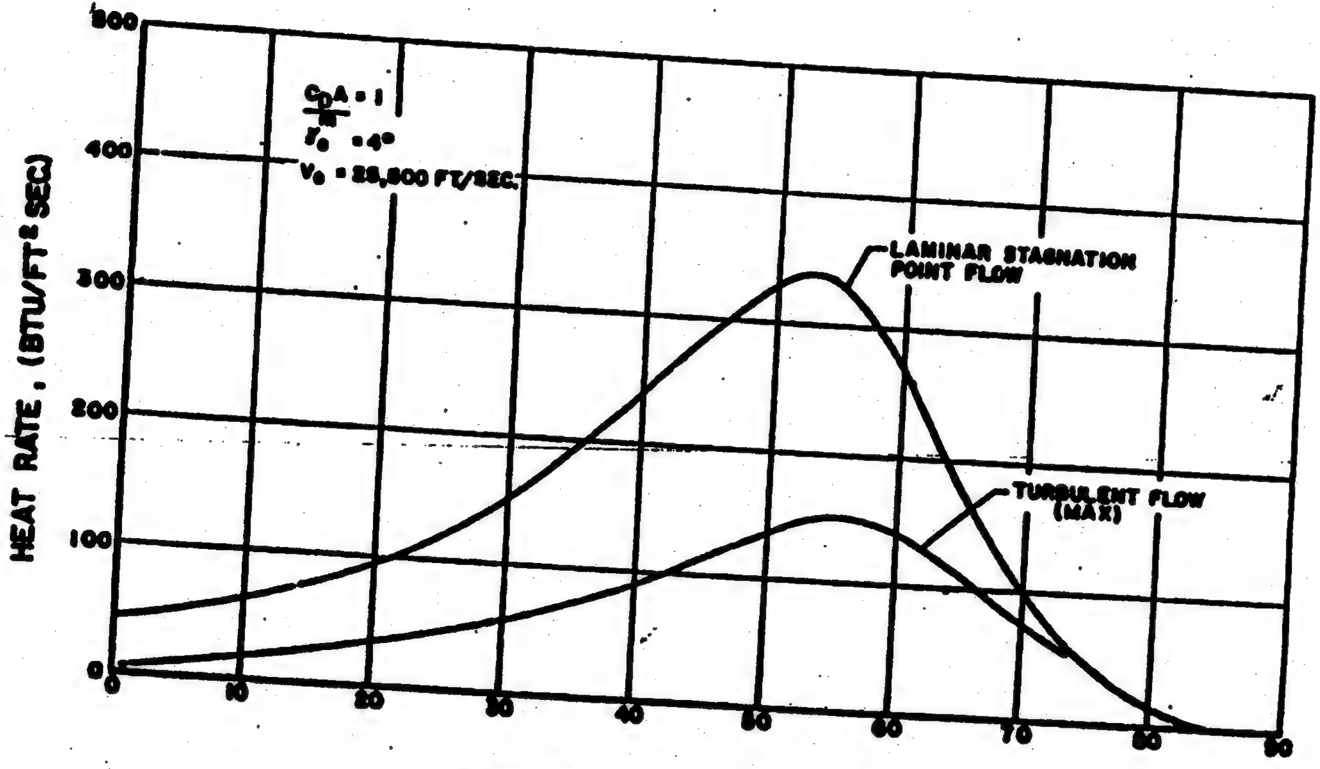


Fig. 4-12 Heat Transfer Histories for a 2 ft Diameter Sphere

[redacted]

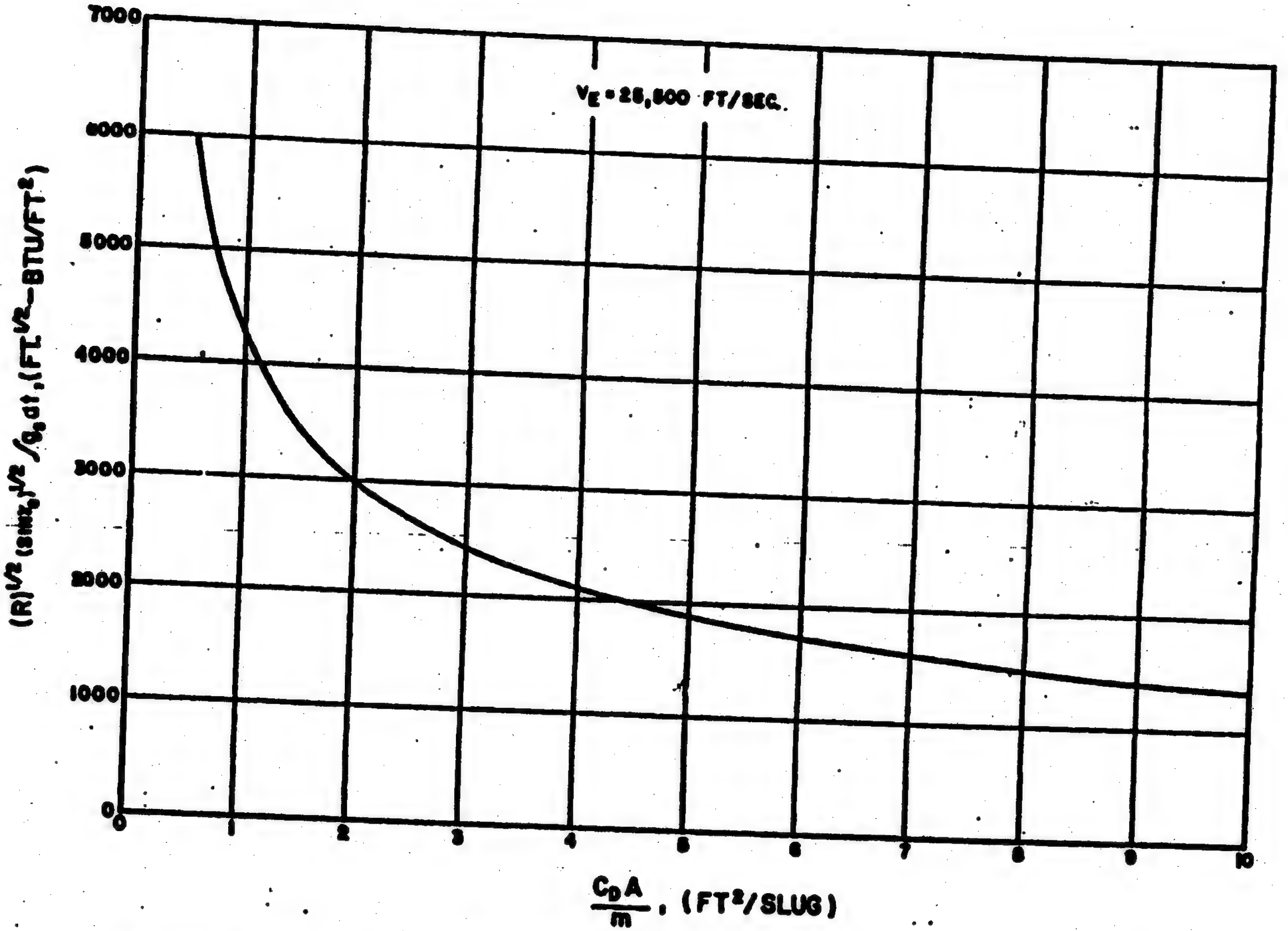


Fig. 4-13 Stagnation Point Total Heat Transfer Parameter, $(R)^{\frac{1}{2}}(\sin\gamma_e)^{\frac{1}{2}}\int q_s\,dt$ Versus Drag-Mass Parameter

[redacted]

This result has been verified experimentally to within 5 percent according to Reference (2). It is important to note that Equation (1) assumes thermal equilibrium throughout the boundary layer, whereas under the flight conditions of interest, non-equilibrium conditions will exist. For the case when the surface is catalytic and aids in atom recombination, the non-equilibrium state of the boundary layer does not affect the heat transfer appreciably. However a non-catalytic surface under non-equilibrium conditions can result in large reductions in heat transfer.

The major contribution to reentry heating will take place when the flight velocity is very high where the total enthalpy of the flow will be much greater than the total enthalpy of the gas at the wall ($h_{sc} \gg h_{sw}$) or

$$\left(1 - \frac{h_{sw}}{h_{sc}}\right) \cong 1$$

and Equation (7) reduces to

$$q_o = \frac{C_o}{\sqrt{R}} \sqrt{\rho/\rho_{sc}} \; u^{3.24}$$

Allen and Eggers (Reference 3) obtained a closed form expression for the flight velocity of re-entering bodies based on the assumptions that the effect of gravity is negligible in comparison to drag forces and that the flight path angle, γ, remains constant.* The density variation with altitude was approximated by an expression of the form:

$$\rho/\rho_{sc} = C_1 \, e^{-\beta y}$$

where C_1 and β are constants and y is altitude.
Their result for the flight velocity u can be written as:

$$u = u_e \, e^{-\frac{C_d A}{2} \frac{C_1 \rho_{sc}}{\beta m \sin\gamma} e^{-\beta y}}$$

---

*It has been shown in separate studies that the use of the simplified trajectory equations leads to conservative estimates of total heating for the shallow re-entry angles of interest.

[redacted]

where $C_1 = 0.79$ and $\beta = 1/24800$ were used in Equation (3) to represent the density variation in the altitude range where the majority of the heating occurs ($140{,}000 \leq y \leq 300{,}000$ ft.).

For the range of conditions of interest,

$$\operatorname{erf}\sqrt{32.2\,\frac{C_dA}{m\sin\gamma}} = 1$$

and for an initial velocity of 25,300 feet per second, Equation (7) becomes

$$(Q/A)_o = \frac{4220}{\sqrt{R_N}\,(\sin\gamma)^{1/2}\left(\frac{C_dA}{m}\right)^{1/2}}$$

The stagnation point total heat transfer parameter, $(Q/A)_o\sqrt{R_N}\,(\sin\gamma)^{1/2}$ is shown as a function of C_dA/m in Figure The integrated stagnation point heat transfer increases rapidly with decreasing C_dA/m when C_dA/m is small. Since the total heat transfer to the reentry body is directly proportional to $(Q/A)_o$, it is obviously important to maximize C_dA/m in order to reduce total heat transfer and heat sink weight.

The total heat transfer to the body can be written as

$$Q_{tot} = \int_0^{A_s}\left(\int_0^t q/q_o\, q_o\, dt\right) dA_s\,, \qquad \text{(BTU)}$$

where q/q_o is the ratio of local to stagnation point heat rates and A_s is the surface area of the body, exposed to heating.

For laminar flow, q/q_o is independent of Mach number and Reynolds number, hence

$$Q_{tot} = \int_0^{A_s} q/q_o\, dA_s \cdot \int_0^t q_o\, dt$$

[redacted]

where

u_e = initial reentry velocity

C_d = drag coefficient based on area A

A = reference area

m = reentry body mass

The stagnation point heat rate can then be rewritten as:

$$q_o = \frac{C_d}{\sqrt{R}} \sqrt{C_1}\, e^{-\beta y/2}\, u_e^{3.25}\, e^{-\frac{C_d A C_1 \rho_{sc}^{3.25}}{2\beta\, m \sin\gamma}\, e^{-\beta y}}$$

The total heat transfer per unit area to the stagnation point during reentry is equal to

$$(Q/A)_o = \int_0^t q_o\, dt = \int_{y=\infty}^{y=0} q_o \frac{dt}{dy}\, dy, \left(\frac{BTU}{ft^2}\right)$$

but $\frac{dt}{dy} = -\frac{1}{u \sin\gamma}$, so that

$$(Q/A)_o = -\frac{C_o\sqrt{C_1}}{\sqrt{R_N}\sin\gamma} \int_\infty^0 e^{-\frac{\beta y}{2}}\, e^{-\frac{C_d A C_1 \rho_{sc}^{2.25}}{2\beta m \sin\gamma}\, e^{-\beta y}}\, dy$$

Integration of Equation (6) results in

$$(Q/A)_o = 5.1 \cdot 10^{-7} \left(\frac{u_e^{2.25}}{\sqrt{R_N}\,(\sin\gamma)^{1/2}\left(\frac{C_d A}{m}\right)^{1/2}}\right) \operatorname{erf}\sqrt{32.2\,\frac{C_d A}{m \sin\gamma}}$$

In cases involving a spherical capsule, the normalized area integrated heat transfer distribution was taken as 0.459, corresponding to the zero angle of attack case. The area exposed to heating was taken as $2\pi R^2$ and the rear half of the body was provided with the same thickness of material as points 90 degrees away from the stagnation point. When applied to the case of a spinning sphere, these methods are conservative.

The quantity of interest is the weight of material needed to absorb the convective heat load. If it is assumed that the material to be used for heat absorption* has a heat capacity of h, (BTU/lb), and that the total weight of the body is composed of a fixed weight, W_F, plus the weight needed for heat absorption, W_S, it is possible to write

$$W_S = \frac{B + \sqrt{B^2 + 4BW_F}}{2}$$

where

$$B = \frac{A_s^2 \left(u_e^{2.25} \cdot 5.1 \cdot 10^{-7}\right)^2}{h^2 R_N C_d A g} \left\{ \frac{\int_0^{A_s} q/q_o \, dA_s}{\int_0^{A_s} dA_s} \right\}$$

From the standpoint of minimizing the heat sink weight the above relations show that it is important to keep the fixed weight to a minimum. The heat sink weight is also minimized by making B as small as possible. It is interesting to note that for the case of a sphere this implies that the radius should be made small since

$$B \sim \frac{A_s^2}{RA} \sim R$$

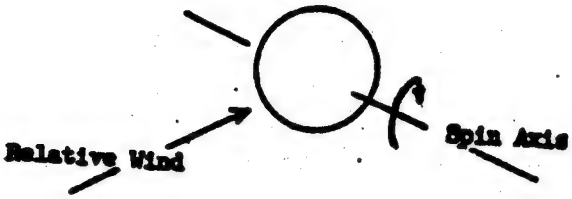
---

*The material may be either an ablator or a metallic heat sink.

$$q_{tot} = \left\{ \frac{\int_0^{A_s} q/q_0 \, dA_s}{\int_0^{A_s} dA_s} \right\} \int_0^t q_0 \, dt \cdot A_s$$

The term in braces depends only upon the body shape, and the dynamics of the body during reentry. For a hemisphere at zero angle of attack it is equal to 0.459. For other bodies, such as cone-sphere, it can be evaluated by using the distribution of laminar heat transfer as given by Lees, (Reference (4)).

One proposal for the recovery of a data capsule involves spinning a sphere about an axis normal to the flight path direction as shown below:



In this case no one point on the body remains at the stagnation point all the time and

$$\left\{ \frac{\int_0^{A_s} q/q_0 \, dA_s}{\int_0^{A_s} dA_s} \right\} \doteq 0.20$$

However, the area exposed to heating A_s, becomes the entire surface area of the sphere.

4.7 Guidance Selection

The guidance consideration of reference 1 were verified but the availability of the ground guidance system assumed appears doubtful. As yet the A.C. Spark Plug system has not flown, but it appears that it will be available early in 1958 and will be checked out by late 1958.

In the selection of a guidance system for this program two factors of nearly equal importance must be considered. One is the time schedule which calls for early firing and use of existing mechanizations - with the corollary of changing the Thor as little as possible. The other is the guidance accuracy (particularly as regards the booster stage) required to achieve the desired orbit parameters, which are orbit altitude of 135 miles with a perigee high enough to give at least several days operation. This probably means a perigee no less than 100 miles.

The imminence of the first firings eliminates the G.E. radio inertial system, or any system not planned for Thor, since the Thor would require modification. On the other hand, the A-C Spark Plug all-inertial system is already installed in the Thor and will have had several shake-down flights before the first proposed Thor-117L firing.

The A-C Spark Plug system contains three integrating accelerometers having an accuracy better than 0.1 per cent. Assuming that boost will carry the vehicle to an altitude of about 3×10^5 feet with a speed of about 12,000 pfs, then it will be known from the A-C Spark Plug system that an orbital boost velocity of 13,500 fps will be required. The time to coast to apogee can also be determined by this system to within about 2 seconds. The major source of uncertainty here will again be the cutoff speed, as the altitude of cutoff will be known to 2,000 feet (assuming .5 per cent accuracy) and the flight path angle should be known to within .0005 radian (assuming gyro drift of 0.5 degree per hour).

Obviously, the radius cannot be made arbitrarily small because of packaging considerations. Even without size limitations, the heat rates will eventually become intolerably large as the radius is decreased.

To summarize, closed form expressions have been derived for the total heat transfer and heat sink weight of bodies entering the atmosphere from a tellite orbits.

References

1. Fay, J. A., and Riddell, F. R., "Stagnation Point Heat Transfer in Dissociated Air," AVCO Research Lab., Res. Note 18.
2. Kemp, N. H., and Riddell, F. R., "Heat Transfer to Satellite Vehicles Reentering the Atmosphere," Jet Propulsion, Vol. 27.
3. Allen, H. J., and Eggers, A. J., "A Study of the Motion and Aerodynamic Heating of Missiles Entering the Earth s Atmosphere at High Supersonic Speeds," NACA RM A 53 D 28, August 25, 1953.
4. Lees, L., "Laminar Heat Transfer Over Blunt-Nosed Bodies at Hypersonic Flight Speeds," Jet Propulsion, Vol. 26, April 1956.

Because of this uncertainty in vehicle velocity at cutoff, the time to coast to apogee and the apogee speed and altitude will be uncertain. In particular, if the magnitude of the cutoff velocity is uncertain by 50 fps and the flight path angle is uncertain by 1 degree, the time to coast to apogee will be uncertain by about 10 seconds. The rate of change of central angle near apogee is about .0005 rad/sec and the rate of change of the flight path angle is about 3.25 times this or .00163 rad/sec. Thus, the 10 seconds causes an uncertainty in the direction of velocity at the beginning of orbital boost of .016 rad. This will cause an eccentricity of about .008.

The uncertainty in apogee speed due to the above effects will be about 190 fps. This will cause an eccentricity of about .015. The effect of these plus the errors from orbital boost added on a root sum square basis predict an eccentricity of .018. This number is most sensitive to direction of cutoff velocity.

The effects due to uncertainty in both Thor cutoff and apogee altitudes have been neglected as they are quite small.

The effect on (Δa) the semi-major axis variation is contained in the uncertainty in apogee velocity magnitude. From the above values, one gets a mean altitude of 135 ± 62 miles and the altitude variation on a given flight (apogee to perigee) (i.e. due eccentricity) would be the mean altitude ± 74 miles.

Returning to the consideration of whether the large weight of the A-C Spark Plug system compromises the performance of the overall system, one can see that any evaluation must be made in light of the above. In particular, the possibility of the low perigee probably demands that the nominal mean altitude would have to be increased about 90 miles in order to keep the minimum perigee above 100 miles. If this is indeed true, one can then say that removing the A-C Spark Plug platform from the system is approximately equivalent to

With this information available, the interim system presently envisioned for the 117L vehicle in the Atlas-117L combination can be used. This will include a horizon scanner* (in conjunction with a 2 to 4 degree per minute pitch down program) to keep the thrust vector of the final stage horizontal. It will also use an integrating accelerometer to measure the magnitude of velocity gained in orbital boost.

Using the horizon scanner, it should be possible to keep the thrust vector within 0.006 radians of horizontal. This will permit an orbital eccentricity of about .0034. The magnitude of the velocity gained in orbital boost will be known to within 45 fps if an integrating accelerometer or equivalent with 0.3 per cent linearity is used. This will add about 0.0035 in the eccentricity. Adding these two major contributors on a root sum square basis gives an orbit eccentricity of .0054. With the small contributions from other sources, a figure of .006 for the eccentricity seems reasonable.

Another factor is the variation of the semi-major axis. This is affected primarily by the variation in the magnitude of orbital boost velocity. In particular, if the injection altitude is $R_o = 4120$ miles, the variation is $a = 2R_o \; v/v$ or $a = 15$ miles.

Thus, the mean altitude (a) from flight to flight will be about 135 ± 15 miles and the altitude on a given flight (perigee-apogee) will be the mean altitude ± 25 miles.

If the A-C Spark Plug platform is not included in the system, the uncertainty in the actual coasting (or ascent) ellipse achieved is increased. In particular, without an inertial platform, inertial accelerations cannot be measured; and, although a body mounted accelerometer (plus integrator) can be used to give an indicated speed gained that has a high correlation to actual speed gained, the direction of the velocity is uncertain. In fact, any knowledge of the velocity is dependent upon the vehicle following a standard programmed trajectory.

requirements due to the reduction in body weight. The large difference in drag between body and shield will provide positive separation and different impact points.

4.8.3 Recovery Technique

The re-entry body will be tracked during its decent to earth via its beacon-transponder system. This same beacon will be examined to see if it can provide location information after impact. A change of antennae will be required upon impact in water and may be done with simple devices and high reliability. Night time impacts will be part of the tactical useage and a visual back-up of the beacon may be provided by a high intensity flash lamp. A long flash duration (approx. one millisecond) will permit clear weather visual detection for approximately 20 miles. Blanking off of the lamp's rays by waves on open sea recoveries will require an elevated observation point. The use of flares is much less effective because of the bulk and weight of pyrotechnic supplies and the auto firing mechanism.

Recovery at sea forces use of further aids to locating the floating body. A bomb may be jettisoned just before impact. The detonation of the bomb in the water will permit approximate location of the impact site by SOFAR facilities. For final direction of the recovery crew a buzzer attached to the body airframe will provide sonar tracking for a distance greater than the SOFAR location ambiguity. Protracted signalling may be achieved on the available batteries by pulsing the buzzer at intervals. *

Recovery of the body at sea may be accomplished most readily by use of a net. The net may be towed by helicopter, surface vessels, or submarines. The submarine is a most effective retrieving vehicle as they may lay submerged at depth, deployed along the expected impact trajectory. The shallow water penetrations of a re-entry body of the type proposed poses no danger to the submarines and permits recovery in a minimum of time as protection against attempts of hostiles to capture or destroy the re-entry body.

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* For daytime recovery by aircraft a dye marker will be necessary to pin-point such a small object. For this particular application, a dye in liquid form may be continuously dispersed by simple mechanical techniques.

requiring that the whole final stage be boosted an additional 90 miles on the average. Another minor compromise implicit in this second mechanization is the more eccentric orbit and, thus, the potential loss in resolution when reconnaissance occurs near apogee.

4.8 Recovery Consideration

4.8.1 Introduction

The following discussion considers the problems of terminal re-entry and recovery of a photographic satellite. A body capable of successful re-entry is assumed. This hypothetical body is assumed to weigh approximately 250 pounds and is designed to withstand thermal effects and to have a terminal velocity of approximately 400 ft/second. The object of the recovery is to bring back photo intelligence in the form of exposed film. Once the film is safely returned to the earth the vehicle must be located and recovered. The various techniques to accomplish these tasks are segregated in the following discussion by recovery phases.

4.8.2 Deceleration

The terminal velocity of the re-entry body is estimated at 400 ft/second. This moderate velocity permits consideration of impacting the body in water and floating until recovery. To successfully accomplish this type of recovery requires that equipment be able to withstand a shock of 1000 to 2000 g's on impact.

If conventionally shock rated equipment is to be used in the body the impact velocity must be sharply reduced. A final approach velocity of 40 ft/second will create a very mild impact of 10 or 20 g's which is readily withstood by conventional equipment. Ruggedized equipment would be good for 100 g's or approximately 100 ft per second final approach velocity. These low approach velocities may be most easily achieved by use of a small parachute. Deployment of the chute can be reliably triggered by a timer set off by the initial re-entry deceleration. The use of "Q" or altitude switch is not considered because of large variations in Q and lack of reliable static pressure reading points. Unlatching the re-entry heat shield prior to chute deployment will decrease chute

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RECONNAISSANCE SYSTEMS DIVISION
Fairchild Camera and Instrument Corporation
Robbins Lane, Syosset, New York

Proposal No. SME-CA-18
2 January 1958

VERY HIGH ALTITUDE

PANORAMIC CAMERA SYSTEM

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RECONNAISSANCE SYSTEMS DIVISION
Fairchild Camera and Instrument Corporation

Proposal No. SME-CA-18
2 January 1958

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SECTION I

INTRODUCTION

PRELIMINARY DESIGN STUDY

This preliminary design study includes the establishment of parameters for a special purpose reconnaissance camera and a preliminary discussion of the proposed camera design consistent with these parameter requirements. The starting point in arriving at the proposed parameters was the vehicle operational features and the conditions set forth for the reconnaissance mission. It was extremely gratifying to find that the parameters established as necessary to fulfill the requirements for this mission were both practical and reasonable, and represent a straightforward design approach that can be accomplished in the relatively short time span spelled out for this program.

The techniques to be applied to this proposed camera design are all proven approaches, leaving no unknowns to possibly upset the progress of the program. Fairchild is confident that it can produce the required reconnaissance tool for this mission with the highest degree of reliability because of the tried and proven techniques to be applied.

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SECTION II

DESIGN CONSIDERATIONS

The design parameters set forth in this section are based on the operational features of the vehicle and the photographic conditions and requirements itemized below.

1. Vehicle Speed = 25,000 ft./sec. = 4 minutes of arc/sec.
2. Vehicle Altitude = 156 ± 35 nautical miles.
3. Vehicle Spin Speed = 18.2 revolutions per minute.
4. Vehicle Acceleration - 10 g's launching acceleration.
5. Vehicle Return - approximately 150 g's (Salvage exposed film only.)
6. Vehicle Power Supply = 28 volt D.C. (Battery Supply).
7. Camera Control - Ready and trip pulses from vehicle (high impedance pulse).
8. Maximum weight of camera - 50 pounds (including film).
9. Minimum reactions on vehicle required for camera operation.
10. Camera Environments - Vehicle can be pressurized and temperature controlled.

The requirements itemized below were either established or derived in relationship to above features or each other.

1. Camera operating time - six active passes of 12 minutes per pass - total 72 minutes of operation.
2. Transverse angular coverage - 93 degrees.
3. Exposure Condition - 70 degrees North latitude.
4. Overlap - 10% overlap of ground coverage in forward direction required minimum.

[redacted]

5. Resolution required - detect 60 ft. object on the ground.

6. Smear permitted due to undesirable motions of image - 6 ft. on the ground. (This is referred to as the S factor).

> 7. Camera lens - 12 inch focal length.

8. Film width - 5 inch film.

Starting with the above listed features, requirements, and/or conditions, the following sections are devoted to establishing the basic parameters of the camera and a preliminary design study of the actual hardware requirements.

A. ESTABLISHING BASIC PARAMETERS

1. Camera Cycling Rate and Scan Time

In order to insure at least a ten percent overlap of ground coverage at vertical, the minimum altitude is used in conjunction with the vehicle speed to determine the rate at which photographs are to be taken. This minimum altitude is 156-35 or 121 nautical miles which is equivalent to 736,000 feet. The effective film width to be used is 4.5 inches with a 12 inch focal length lens. At the minimum altitude, therefore, this film width represents 276,000 feet or 52.4 statute miles on the ground in the direction of vehicle motion. For ten percent overlap, pictures must be taken when the vehicle covers a distance of ten percent less than 276,000 feet or 248,400 feet. Since the vehicle travels at 25,000 ft./sec., the time required for it to travel 248,400 feet is 9.94 seconds. The camera cycling rate must be at least one picture every 9.94 seconds. Since the vehicle rotational spin rate is 18.2 revolutions per minute, it makes one revolution every 3.3 seconds. Hence, it is required that the camera be pulsed every third revolution of the vehicle, which is every 9.9 seconds and this is completely compatible with the requirements for overlap. Actually, of course, the overlap will be greater for higher altitudes and for all scan angles off the vertical.

The very nature of the vehicle operation calls for panoramic photography with the vehicle rotational spin rate determining the scan time per photograph. Since the effective transverse coverage is 93 degrees, the time to scan this angle turns out to be .852 seconds. During this time, since a 12 inch focal length lens is used, 19.5 inches of active format length of film is scanned at a rate of 22.9 inches/second.

2. Resolution and Exposure Considerations

The resolution requirements and exposure necessary in a reconnaissance camera are closely allied functions. Invariably, the parameters selected must be a compromise to give the best overall performance rather than being able to choose the ideal parameters for each requirement. Since image motion exists due to vehicle motion and complete compensation for all these undesirable motions is complex and at best only partially compensated for, short exposure times are necessary to limit the smear or blurring of the image during exposure.

Experimental work in connection with varying amounts of relative motion (motion between film and image) have been performed (Romer[1] and Gregory[2]) showing the degradation in resolution with motion. These experiments were carried out with actual lens-film-camera combinations and with precisely controlled motion being introduced to observe the degradation.

By using a starting resolution (static test of lens-film-camera in laboratory) of some 40 to 50 lines/mm on Plus-X Aerocon emulsion (S.O. 1166) the angular disturbances which would effectively degrade this during a 1/4000 second shutter are of the order of 0.00005 degree or 11 degrees per second. Since the latter value may be considered as a couple of orders of magnitude out, the stability of the vehicle will be considered entirely negligible.

A second disturbance may be considered as originating in the rotational speed and the firm tie between vehicle rotation and photographic exposure.

An error of + 1% in the rotational speed from the designed photographic film scan speed will result in an error of 0.229 inches per second for a duration of 1/4000 second or a residual relative motion of .00005 inches. This value is in addition to any slippage of film or other mechanical errors.

The design objective for this would be to hold the relative motion to less than 0.0006 inch from all causes. Such a relative motion would degrade the 40 - 50 lines/mm to 35 - 42 lines/mm respectively. A preliminary error analysis has indicated that the total unwanted relative motion should be considerably less than the .0006 inches discussed here. The projection of these resolution values to the ground result in a ground resolution of 90 feet and 78 feet respectively. While these values are presented as a rather

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1. "Suppression of Image Movement in Air Photography" - W. Romer, D. Techn. Sc., Poland, F. Inst. P., F.R.P.S. Royal Aircraft Establishment, Farnsborough, Hants, England.
2. "Interim Reports on the Effect of Image Movement on the Definition of Air Photographs" - J. M. Gregory, Kodak Research Labs; Harrow England, ATI165074, F52-2-1947 Reel C -3723.

exacting value, it should be pointed out that photographic information content is not a direct function of resolution for several reasons, such as identification and recognition of intelligence through previous knowledge.

With given light conditions of aerial photography, a short exposure time usually demands a large aperture lens and/or high speed film emulsions. Unfortunately, both large aperture lens and high speed film emulsion parameters lead in a direction of reduced resolution capability. Specifically in the case of this program where the delivery time for the hardware prohibits new developments in lenses and film emulsions, it is necessary to select the best known components available to arrive at the best overall result.

Fortunately, the exposure conditions established help this compromise and permit using a short exposure time that greatly simplifies the design and promises to give relatively high acuity photographs. The exposure considerations made for the conditions of operation as set forth appear to have no requirement for a conventional automatic exposure control (AEC). The photographic time period being approximately noon at latitudes up to 70°N, the brightness values will be approximately as follows:

Seasonal Change	Reflective Brightness (100% of atmosphere below camera)	
Sun at	70° N Latitude	
14° N	1110 ft. Lam.	May 20
16° N	1170 "	
18° N	1230 "	
20° N	1282 "	
22° N	1335 "	June 20

Using these values for the exposures required under the most severe conditions of 70° N latitude, a combination of parameters as follows appears to be entirely feasible and practical. These parameters, of course, were decided on in conjunction with lens availability and film emulsion considerations.

Exposure Time = 1/4000 second

Lens Aperture = f/3.5

Filter Factor = 2

Film Emulsion Speed = 80 A.S.A.

This combination of conditions indicate an under-exposure of approximately one stop. This can be compensated for in processing by known techniques.

3. Lens and Film Emulsion Considerations

The lens which is presently being proposed is the 12 inch version of the f/3.5 Eastman Kodak Formula M-351A. This is a 6-element Gauss type design which has an unusually high order of oblique spherical correction resulting in very high contrast images across the usable field. It has been achromatized over the spectral range of 486 to 656 milli-microns for use primarily with a minus blue filter in aerial cameras. Its high resolution is made possible through the use of four high index Kodak glass elements. It is, as far as is known, significantly superior to any other proven lens design, for which delivery can be made with reasonable assurance.

Photographic tests have been made by Eastman Kodak on samples of the 12 inch M-351A design. On Plus-X Aerecon emulsion (Eastman's production designation of S.O. 1166), the minimum resolution, tangential or radial, was 40 lines/mm except at the extreme edges of the 4-1/2 inch slit where it fell to 35 lines/mm. These tests were made with the lens adjusted to cover a 4-1/2 x 4-1/2 inch format. With the lens adjusted for the narrower field required by the 4-1/2 inch slit, Eastman feels they could in all likelihood guarantee a minimum resolution of 40 - 45 lines/mm with an average of 45 - 50 lines/mm across the entire slit. These tests were made using high contrast targets illuminated with white light filtered through a minus blue filter conducted in accordance with Method 7 of MIL-STD-150. No results are available on the resolution in lower contrast targets, though the lens-film combination will give a proportionately higher resolution compared to the resolution of the film, as the contrast is reduced. That is, the Plus-X Aerecon high contrast resolution is about 100, and at an illuminance ratio of 2:1 drops to about 50 lines/mm. However, for the lens with an object contrast of 2:1, the resolution will be significantly better than 25 and can be expected to run closer to 35 lines/mm.

The resolution on Super XX was generally about 80% and on Tri-X Aerecon about 60% of that obtained with Plus-X Aerecon. Although the speed of the Plus-X Aerecon is rated somewhat lower than Aero Super XX (80 ASA to 100 ASA) its far wider range makes it much more susceptible to overdevelopment and effectively higher speeds. For these reasons Plus-X Aerecon is being proposed.

Although the Eastman lens is being proposed for the first units, a parallel program will be carried on to develop a more elegant design, capable of producing images good enough to make the information content on the film essentially limited by the emulsion. Of the various solutions we have been able to investigate in the limited time available, the most promising appears to be a modification by the Perkin-Elmer Corporation of a design developed by Dr. J. G. Baker. This design at f/2.8 is expected to give a minimum resolution across the 4-1/2 inch slit (at an object illuminance rate of 2:1) very close to the capability of the emulsion of Plus-X Aerecon, which is about 50 lines/mm. However, it would be unrealistic to expect a lens representative of the design capability to be ready in time for the first units. There is a lead time of three to four months on delivery of the glass and the design involves the use of accurate aspheric surfaces which are notorious for requiring a longer than usual amount of recomputation and refiguring of surfaces before a good sample lens is available. The new lenses will be phased in just as soon as they become available.

The lens philosophy discussed above has been discussed with and agreed upon by Dr. J. G. Baker.

4. Temperature and Relative Humidity Sensitometric Effects

A change in gamma of +0.2 may be experienced at the extremes of temperature presented (0°F to 150°F), however, a complete environmental test program will undoubtedly show that this may be adjusted for in the ground support equipment.

Some apparent loss in emulsion speed may result at these extremes of temperature. Under the preferred set of temperatures a maximum loss of 20% should be considered applicable. In this case, ground support equipment definitely will be capable of making up what may appear as an actual loss.

During the expected life the fog level will not be adversely affected up to the 140°F level. Shorter periods, say up to one hour at temperatures of 210°F, will be tolerated without an appreciable rise in fog level.

If the relative humidity drops to an order of 2% to 5% the film exposed in loop form will almost certainly become brittle within a matter of a few minutes (5 - 10).

The summary of temperature and humidity relationships may best be expressed as follows:

Temperature

Long Term (0 - 9 hours)

Absolute Maximum	+150°F
Preferred Maximum	+120°F
Absolute Minimum	0°F
Preferred Minimum	+ 20°F

Short Term (0 - 1 hour)

Maximum	210°F
Minimum	- 20°F

Relative Humidity

Under Preferred Temperature Range	15-20% minimum 35-40% maximum
Under Extreme Temperature Range	10-15% minimum 20-30% maximum

5. Image Motion Considerations and Synchronization

Since the exposure time decided upon for this proposed camera has been established at 1/4000 second, the smear or S factor due to forward motion is approximately six feet for average altitude at vertical. The effective altitude and scale factor is a variable for the panoramic for each angular increment in transverse scan. Also, since the actual altitude itself has a considerable tolerance, there is a variation in extremes of scale factor from minimum altitude vertical of 736,000 to maximum altitude at 45° of 1,642,000. An average compensation for the smear can be easily accomplished by skewing the film motion direction slightly from the optical scan direction to give a forward motion component to the film. This average compensation angle is approximately 40 minutes.

From this analysis it is realized that the optical spin axis must be known to very close angular tolerances so that the film scan axis can be aligned properly within the vehicle. In order to make the compensation significant it is assumed that the alignment should be within about five minutes of the average correction to be set in. This calls for mounting provisions on the vehicle and on the camera to close mechanical tolerances to the respective axes.

Again using the S factor as a criterion, unwanted rotational rates of the vehicle during exposure calculate out to be approximately 2 degrees per second maximum in any direction to give the smear of .0001 inch on the film plane or about six feet on the ground. It is assumed that rates of this order of magnitude will not be encountered in flight and hence, no steadying or stabilization is required.

Along with the requirement of alignment of axes is the requirement of synchronization between optical scan rate and film motion rate. Any significant errors between these rates result in a first order error in unwanted image motion and resulting smear. Again using the S factor as a criterion,

[redacted]

the maximum percentage error permitted between the two rates is 1-3/4 percent. It is felt that the appropriation of one percent to the vehicle scan rate will be satisfactory. It is proposed that the actual scan rate be known to within one percent and that this be designed into the camera or pre-set prior to flight. Actually, it is felt that on the basis of resolution degradation discussed earlier that a greater error in known value of vehicle spin rate can be tolerated, say two percent, before the degradation becomes appreciable. To keep the camera simple and reliable it is highly desirable to use a pre-set motor speed.

6. Film Capacity

The active format length for each photograph is 19.5 inches and allowing about one-half inch for acceleration and deceleration of film, and about one-half inch for time errors of about 20 milliseconds, the total amount of film consumed per scan is 21 inches. For twelve minutes of photography per pass and six total passes, the capacity works out to be 763 feet required. It was decided to provide 800 feet to allow for threading and some pre-flight testing. Thin based film was considered but the lack of availability ruled this out. It is proposed to use five inch standard perforated film that was successfully used in a recent Fairchild Panoramic Camera development. This film was provided by Eastman Kodak who will also provide the S.O. 1166 emulsion established.

7. Data Recording Considerations

The data recording prepared for this reconnaissance camera will include a twenty-four hour clock with a sweep second hand to be recorded on each photograph, together with an exposure counter. Timing marks can be included along the edge of each format if desired, but since each photograph scans in less than one second it is felt that the clock should suffice. A relatively simple flash package has been devised, operating from a 28 D.C. pulse that can be used to flash the nadir, but this requirement must be further studied as recommended in the section on Stereo-Viewer.

8. Description of Camera and its Operation

The camera design study is shown on Figure No. 1. The camera occupies approximately half of the vehicle cross-section.

The camera consists of an open frame attached to the vehicle structure. Two detachable light tight cassettes are mounted on the camera frame. The lens cone is provided with a light shield extending from the vehicle window to the exposure slit. Since the exposure slit has a width of only .0057 inch (see below), the stray light escaping from this slit will expose only a very short portion of the film during the time of film standstill.

The open construction of the camera will allow easy inspection of all operating parts up to the time of sealing the vehicle. The operation of the camera is as follows: During the exposure the camera is rotating around the horizontal axis with a scan velicity $\omega = 1.91$ Rad/sec. The image is projected into the focal plane and is moving across it with the velocity $V = \omega F = 22.9$ in/sec. (where $F = 12$ in.) the film has to be transported across the focal plane exposure slit with the velocity V. To provide for an exposure time of 1/4000 second the exposure slit will be: $s = \frac{22.9}{4000} = .0057$ inches. The film transport mechanism is shown on Figure No. 1 and schematically on Figure No. 2.

Five inch perforated film is used. The pitch distance between perforations is .187 inches.

The unexposed film is housed in the supply cassette. The supply sprocket (14 teeth) feeds the film into the supply loop accumulator. Upon receipt of the scan-pulse the focal plane roller (35 teeth) will transport the film at a synchronous speed "V" across the exposure slit and feed it into the take-up loop accumulator. The take-up sprocket will feed the film from the take-up accumulator into the take-up cassette.

In order to insure synchronous operation of the camera and to reduce acceleration torques, the arrangement described below is proposed.

A 10,000 RPM (75 watts) governor controlled motor drives the supply and take-up sprocket through a suitable gear ratio (approximate gear ratios are shown on Figure 2) and an electro-magnetic film feed clutch. The focal plane roller is driven by the motor through a gear ratio and a solenoid operated single revolution clutch. The speed of the film plane roller has to insure a synchronous velocity of the film ($V = \omega F$) within 1%. The single revolution clutch controls the length of film fed during one exposure. The length of a frame for a scan of 93° is 19.6 inches active, 20.6 inches total, corresponding to 110 perforations on the film. (Ratio of single revolution clutch to roller: $\frac{35}{110} = \frac{1}{3.14}$).

The supply film spool is provided with a friction brake and the take-up film spool is driven through a friction clutch from the take-up sprocket. The gear ratio between take-up sprocket and the take-up spool is such as to insure an overdrive of about 3% for an empty spool.

In order to insure the proper free loop lengths in the accumulators and to prevent excessive spool acceleration torques, a loop sensing control is provided in the camera. This control will consist of two concentric discs, one geared with a ratio of 2:1 to the output side of the single revolution clutch and the second driven through a proper gear-ratio from the supply sprocket. The outer disc will have a micro switch mounted on it as shown on Figure 2, the second disc will be provided with a switch operating cam. Slip rings for the micro switch will also be provided. The operation of the loop sensing control will be described below.

At the beginning of the operation the motor is at standstill, the supply spool is full, the supply side accumulator loop is approximately 22 inches long, the take-up side loop is short and the take-up spool is empty.

The ready pulse latches in relay #1 and starts the motor. The two film feed sprockets start feeding film and the 1/2 Rev. shaft of the loop sensing control starts rotating. When the cam of the loop sensing control actuates the switch the film feed clutch is disconnected and the film feed sprockets stop. The motor is continuously rotating. When the scan pulse operates Relay #2 the single revolution clutch is actuated and the focal plane roller transports film across the exposure slit with the synchronous velocity "V". After one revolution of the single revolution clutch, the proper amount of film (20.6 in.) is transported and the clutch disengages. The start of the rotation of the output side of the single revolution clutch will also start the rotation of the outer disc of the loop sensing control actuating the switch, which in turn engages the film feed clutch and starts the rotation of two film sprockets. The gear ratios are chosen to feed 20.6 inches of film in 9.6 seconds. This is 3% faster than the nominal pulse rate of 9.9 seconds. The inner disc of the loop sensing control will also rotate 1/2 revolution in 9.6 seconds. Since the outer disc rotates 1/2 revolution after every pulse and the film feed sprockets are disengaged when the cam actuates the switch, the proper amount of film will be fed by the sprockets for any pulse rate slower than one pulse in 9.6 seconds.

In order to stop the camera if no scan pulses are reaching it, a one minute timer is provided. This timer is started by the actuation of the loop sensing control switch (when cam engages the switch) and reset to zero when switch disengages the cam (when scan-pulse actuates single rev.

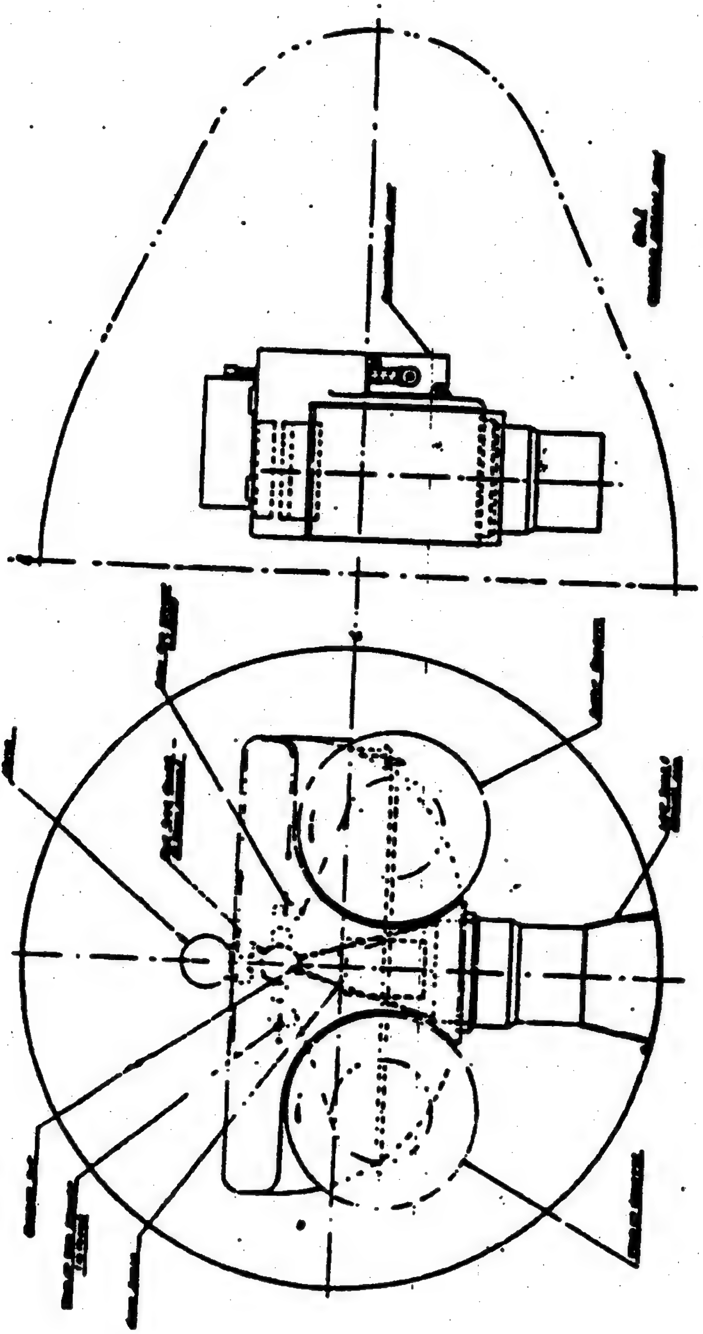
clutch). In case no scan pulses reach the camera for an interval of one minute, the timer will complete its rotation, close a contact and release latch-relay #1, de-energizing the camera.

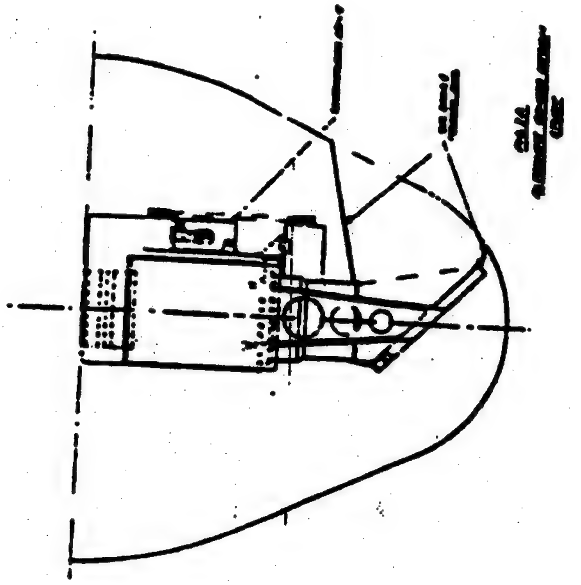
Relay #3 will actuate film cut-off knife, and seal the take-up cassette upon receipt of the re-entry pulse.

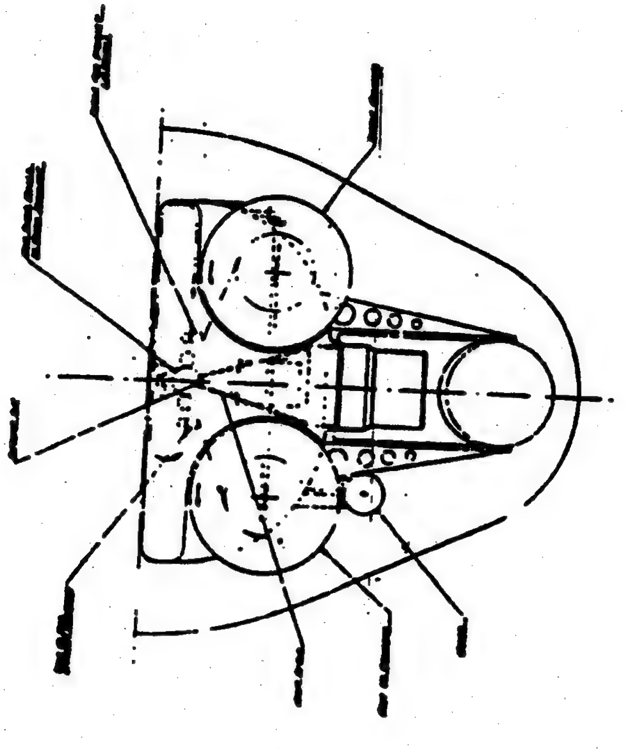
All electrical switches and contac: will be pressure sealed to insure proper operation under vacuum conditions.

A counterweight to counterbalance the shifting film weight and to keep a fixed center of gravity is incorporated into the camera. The film weight is approximately 10.5 pounds. Using a mechanical advantage, the weight will be 8 pounds. It will be driven from the film feed sprockets through a gear ratio and a lead screw. Since the weight shift is proportional to the film feed, no computing mechanism for the weight drive is required.

[redacted]







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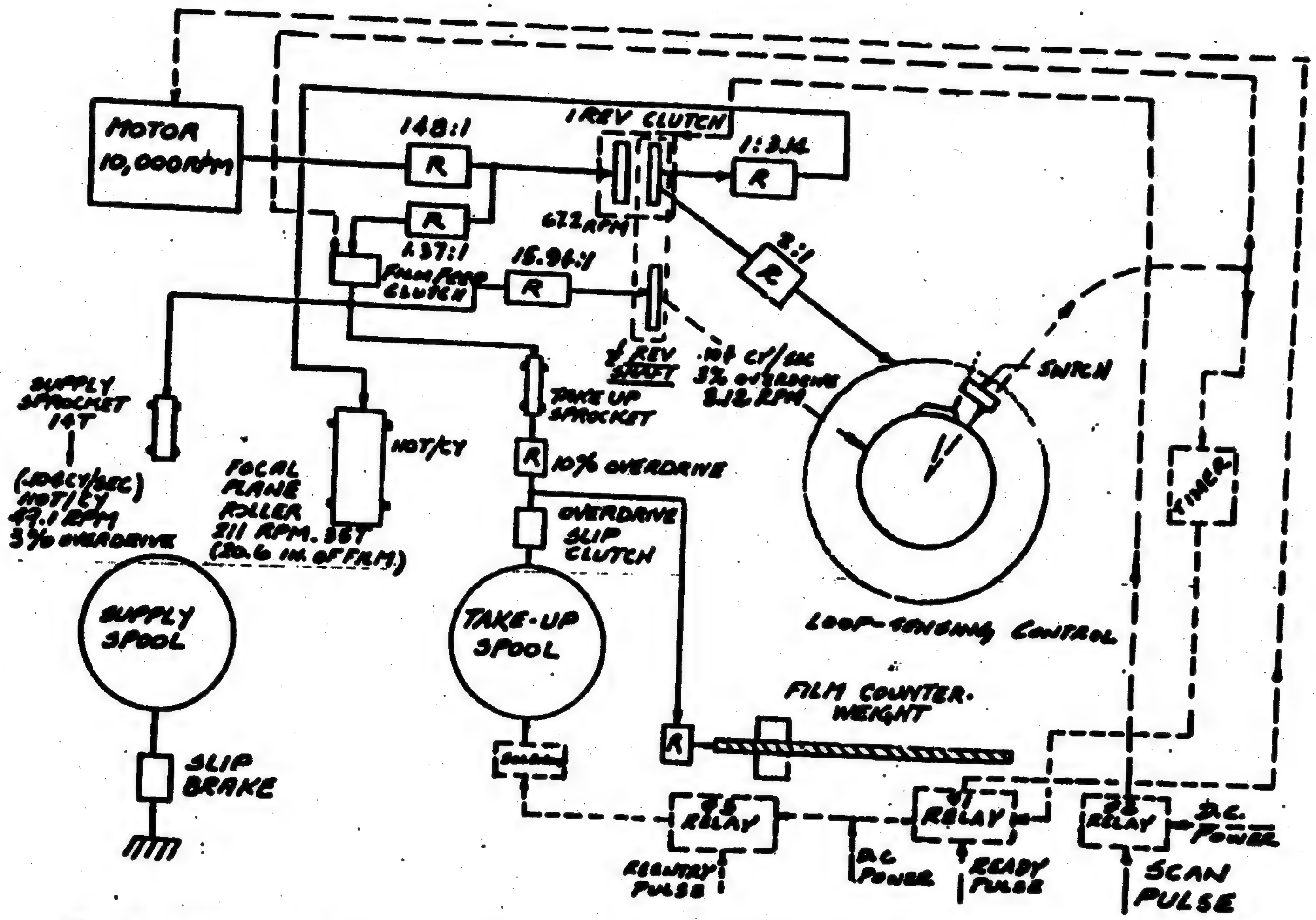

Fig. 2 Schematic of Camera D-ive (for 93° Scan) Reconnaissance Systems Div. Fairchild Camera and Instrument Corp. Propocal No. SWZ-CA-10, 2 Jan. 1958 Fig. 2 Page No. 2-14

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SECTION III

CAMERA REACTIONS

A. Torque Effects

In order not to affect the angular momentum of the vehicle it is necessary that the camera proper not deliver any torque to the vehicle as a consequence of the angular acceleration and deceleration of the film transport mechanism. A simple and expeditious way of accomplishing this is by having the net vector angular momentum of the rotating parts of the camera vanish under all modes of operation. Thus, for example, if we choose a spacial direction, the angular momentum of the clockwise rotating members must be equal (and opposite) to the angular momentum of the counterclockwise rotating members. It is, of course, necessary to judiciously choose the configuration such that the above requirement is fulfilled without the addition of appreciable extra weight. It should be noted that having zero net angular momentum at any speed of geared components assures that the momentum vanishes at all speeds. Experimentally, or in fact even as a pre-flight check, if necessary, the accuracy with which this has been accomplished can be determined by supporting the camera on bearings or on a torsion wire and noting the reaction on start-up.

B. Thrust Effects

The only linear momentum associated with the camera is caused by the motion of the film and the associated counter-balancing weight. If the center of gravity of these two is on the average at the center of gravity of the craft, then the only resulting thrust will be a periodic one caused by acceleration and deceleration of the film alone. The average of the periodic thrust is also zero. If this thrust passes through the center of gravity of the craft, it produces a small perturbation in its linear velocity. This velocity perturbation can be obtained from the conservation of momentum ($m_1 v_1 = m_2 v_2$)

Craft weight 300 pounds assumed
Film in transport 2 feet = .03 lbs.
Film velocity 1.8 ft/sec.

$$v_1 = \frac{m_2 v_2}{m_1} = \frac{.03}{300} \times 1.8 = 1.8 \times 10^{-4} \text{ ft/sec.}$$

which is completely negligible. If the thrust does not have zero moment arm but is one foot from the C.G., it will cause an angular velocity change, which can be obtained from the conservation of angular momentum. Assuming the moment of intertia of the craft to be 150 lb. ft.^{2}, the peak change in angular velocity is as follows:

$$\Delta W = \frac{.03 \text{ lbs.} \times 1.8 \text{ ft.} \times 1 \text{ ft.}}{150 \text{ lb. ft.}^2 \text{ sec.}} = 3.6 \times 10^{-4} \ \frac{\text{Radians}}{\text{sec.}}$$

This too is thoroughly negligible.

SECTION IV

FILM RECOVERY

The take-up cassette will be constructed to withstand the heating and accelerations which will be encountered during re-entry and ground contact. Although the exact nature of these factors is not clear at the time of this writing because of the limited information available on the vehicle and the re-entry flight profile, we are confident that a design basically like that shown in Figure 3 will be adequate if the vehicle itself can be brought back to the surface without complete burnout.

The basic approach is to enclose the take-up spool in a double walled chamber, the interspace of which, during flight, will become evacuated and at the start of re-entry will be sealed, so that in effect the film will be encased in a 'thermos' bottle during descent.

Resistance to the crush forces at impact will be accomplished through the relative frangibility of the outer shell and the interstices between it and the inner shell. The inner shell will be much the stronger of the two and this will resist crushing at least until the gap between them has been closed.

The cushioning effect of the collapsing outer shell will greatly reduce the total "g" forces on the inner shell and thus prevent it from cracking or bursting and exposing the film to light or water leakage.

Sufficient buoyancy will be provided on the inner shell to float the entire cassette even with the outer shell punctured.

Present thoughts are that the entire construction will be of stainless steel - all surfaces highly polished for maximum heat reflectance. This material seems best from the standpoint of its low heat conductivity and high strength-weight ratio. More detailed study later, of course, may indicate that other materials are preferable due to properties not yet fully investigated.

For loading, one end of the cassette will be removable as shown in the drawing, there being a separate gasketed cover for each shell. The spool drive will be brought through the center of these covers using thin walled shafts of low conducting material.

A spring loaded scissor-type cutting mechanism will serve as the sealing door for the film aperture as well as the film cutter.

At installation a thin tube will be connected between the outer shell of the cassette and the outer skin of the vehicle. During flight the air within the interspace will be bled off through this tube, thus providing complete evacuation prior to start of descent.

Release of the cutting blades upon receipt of pulse at the end of the mission will be initiated by a solenoid actuating a trigger which will require only a small tripping force. This mechanism will be oriented in such a way with respect to the vehicle that the accelerating forces during climb will not tend to trip it.

In closing, the blades will clip the film and seal the film chamber against water leakage. They, or associated mechanism, will also close the bleed line which vents the interspace to the outside, thereby sealing in the vacuum.

Thus for the downward plunge the intelligence carrying film will be sealed within a rugged water-proof vacuum lined container. The outside surface will be highly polished and heat resistant. At impact the brunt of the energy will be dissipated relatively slowly through the crushing of the outer shell.

This design approach, of course, is based on a very quick look at the problem and the application of recent Fairchild experience with insulation of aerial cameras against high ambient temperatures. More detailed study and closer familiarity with other facets of the problem may result in some revisions but this should certainly suffice as a first approximation.

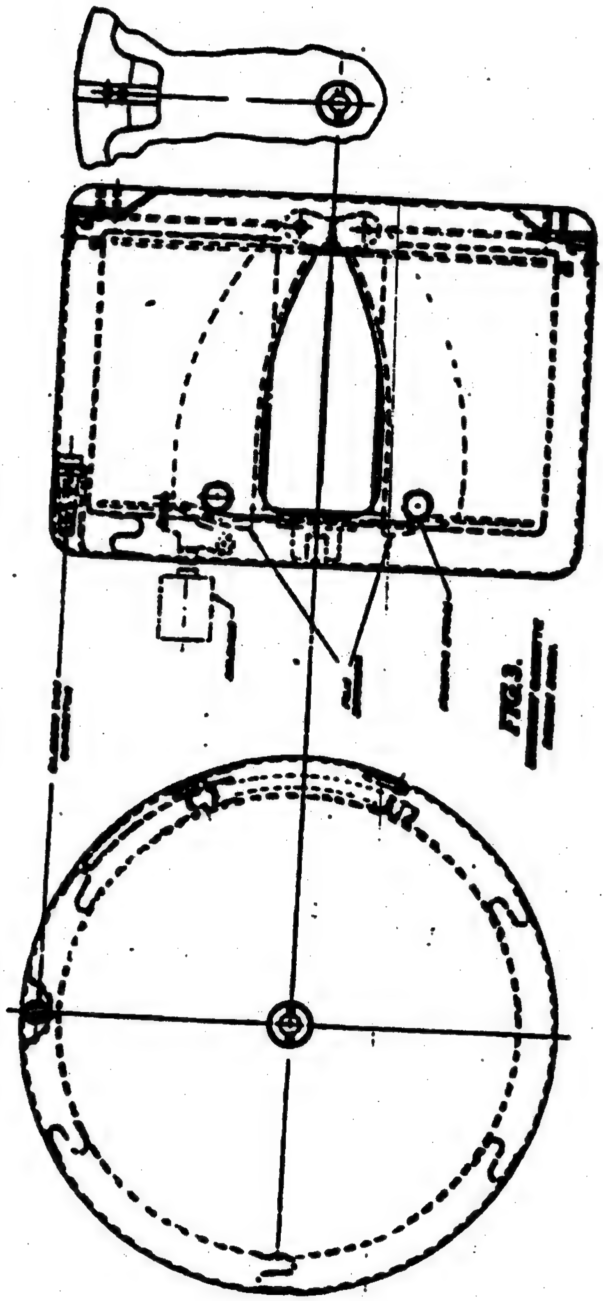

FIG. 3.

[redacted]

SECTION V

GROUND SUPPORT CONSIDERATIONS

Ground support will involve thorough and complete inspection and test which will prove optimum performance of the unit and thereby insure mission success.

Wherever feasible, self-testing features and devices to facilitate testing of critical functions of the unit will be incorporated within the unit. In all cases, however, full consideration will be given to minimize weight in view of the utility of the self-incorporated testing devices.

A maintenance test area is envisioned where the unit will undergo complete inspection and test prior to installation in the vehicle. In this area the unit will be energized with the proper operational voltages and signals. Dummy film may be threaded through the camera unit while visual and instrumented observation of the critical functions of the camera unit are made. Marginal testing techniques will be employed where applicable to predict failure so as to insure satisfactory performance of the unit over the period of flight.

Final tests will be made after installation and prior to release to flight. Such tests will be made at this time to conclude that successful mating with the vehicle power and control signals have been made and that no damage has incurred through handling and transition to the vehicle.

A very precise check of the alignment of the film scan sprocket with the spin axis of the vehicle will have to be made at this time. The exact nature of such a test will have to await more complete liaison with the vehicle manufacturer.

Since the camera is now in the final stage of preparation for flight, live film will be threaded through the camera. At this time, it is considered advisable to check drive motor speed, time to accelerate to correct film velocity, clock and data chart lamps and marker lamp operation, and cutter and cassette door operation. The camera will be cycled while these tests are made. The number of cycles will be carefully metered so as to minimize wastage of live film. After the film has been chopped, the leader will be removed and the take-up spool re-threaded.

For the purpose of measuring drive motor speed a magnetized toothed wheel and magnetic pick-up are recommended. Incorporation of this device within the drive motor of the unit will not substantially increase weight of the unit while providing an accurate means for measuring speed. This device will present a constant load to the motor during test and during normal operation of the camera, eliminating the influence on motor speed during test which may be caused by attaching an external tachometer. Selection of the number of teeth on the toothed wheel will permit accurate determination of speed on an electronic counter. Demodulators and recorders may be used to determine film acceleration period upon initiating the exposure cycle.

Whenever opening of signal or control cables are required to facilitate tests, it is recommended that a shorting connector for test signal leads be provided in the wiring harness to eliminate the need for removing many system connectors and the subsequent possibility of not regaining total contact upon reconnection.

Standard test equipment, such as electronic counters and recording devices supplemented by special electronic test equipment where necessary, are contemplated for test purposes. This equipment will be mounted on commercial available running gear or integrated with the overall vehicle test equipment. Consideration will be given for protective covering and operation during adverse outside operating conditions. Section 3 of MIL-M-8090 will be used as a guide in the design of mobility provisions. MIL-G-008512A Test Equipment, for use with Electronic Equipment, General Specification, will be used as a guide in procuring standard test equipment and in designing supplementary special test equipment.

RECONNAISSANCE SYSTEMS DIVISION
Fairchild Camera and Instrument Corporation

Proposal No. SMS-CA-18
2 January 1958

SECTION VI

VIEWER AND COORDINATE MEASURING DEVICE

Viewer

A coordinate measuring device is proposed with a stereo capability. Inasmuch as end overlap of the panoramic photography will be approximately ten percent at the nadir, only portions of the coverage may be viewed stereoscopically. It will be noted that in such a system only extreme conditions of terrain relief would introduce great enough parallactic angles to afford detection of height differences. However, in portions where overlap is provided, advantage lies in the double observation of the same ground object appearing on two exposures by effectively reinforcing the individual resolutions.

The instrument, as illustrated in Figure 4, will provide coordinate measurements with reference to a system whose y-axis is the trace of the principal point and whose x-axis is a line parallel to the flight line at any instant. It will provide viewing and measurements directly from a continuous roll of film which for maximum interpretation should be a direct contact positive. Translation of a fixed pair of optics will provide measurements in the x-coordinate and y-coordinate measurements will be made by metering the translation of the film. The film will pass over two viewing tables such that conjugate images are presented to the optics. The instrument will be designed in accordance with the principles of good human engineering.

For purposes of determining ground coordinates of imaged points, photo coordinates of the point will be measured with reference to the imaged nadir as an origin, the trace of the principal point as the y-coordinate axis and a line parallel to the flight line as the x-coordinate.

The following expressions will then give the ground rectangular coordinate values of the imaged points in terms of a system in which the x-axis is the flight line, with an origin at the nadir of the vehicle at the instant the imaged point was exposed.

$$X = H \cdot \frac{f \cdot \cos\omega \cdot \sin\phi + x \cdot \cos K \cdot \cos\phi}{f \cdot \cos\omega \cdot \cos\phi - x \cos K \cdot \sin\phi}$$

$$Y = H \cdot \frac{f \cdot \sin\omega}{f \cdot \cos\omega \cdot \cos\phi - x \cdot \cos K \cdot \sin\phi}$$

[redacted]

Where:

H = terrain clearance of vehicle
ϕ = vehicle rotation about an axis transverse to the flight line
ω = the pan angle plus the vehicle rotation about a secondary axis previously rotated through ϕ (See "Photogrammetry, Collected Letters and Essays", by Otto Von Gruber)
K = Rotation of vehicle about the camera optical axis
x = photo coordinate measurement
f = camera focal length

The effects of earth curvature and atmospheric refraction may be considered by converting the x and y-coordinates of the point to the zenith angle of the ray passing from the ground object through the perspective center and the image at the instant of exposure. The astronomic refraction tables may now be used to compute the deviation of the ray. With this information, the geocentric angle subtended between the vehicle nadir and the ground object may be determined directly and the ground distance between the ground point and the instantaneous nadir of the vehicle is thus obtained.

Depending on the justification of refinement, various simplifications of the above expressions may be made to expedite the flow of information.

Since detection of the "beginning of scan" is made by other than the photo reconnaissance system, it is strongly recommended that a recording of this detection be made for use at the time of making photogrammetric measurements. The recording of the output of a horizon detector will serve as a basis in the above formulas for determining the nadir of each photo. For a one mile accuracy this nadir must be accurate to within ten minutes of arc if all error is assumed in the nadir location. This angular accuracy represents approximately one and one-half milliseconds of timing accuracy assuming input pulse is perfect. It is recommended that this nadir recording problem be the subject of an early engineering conference to determine its feasibility.

[redacted]

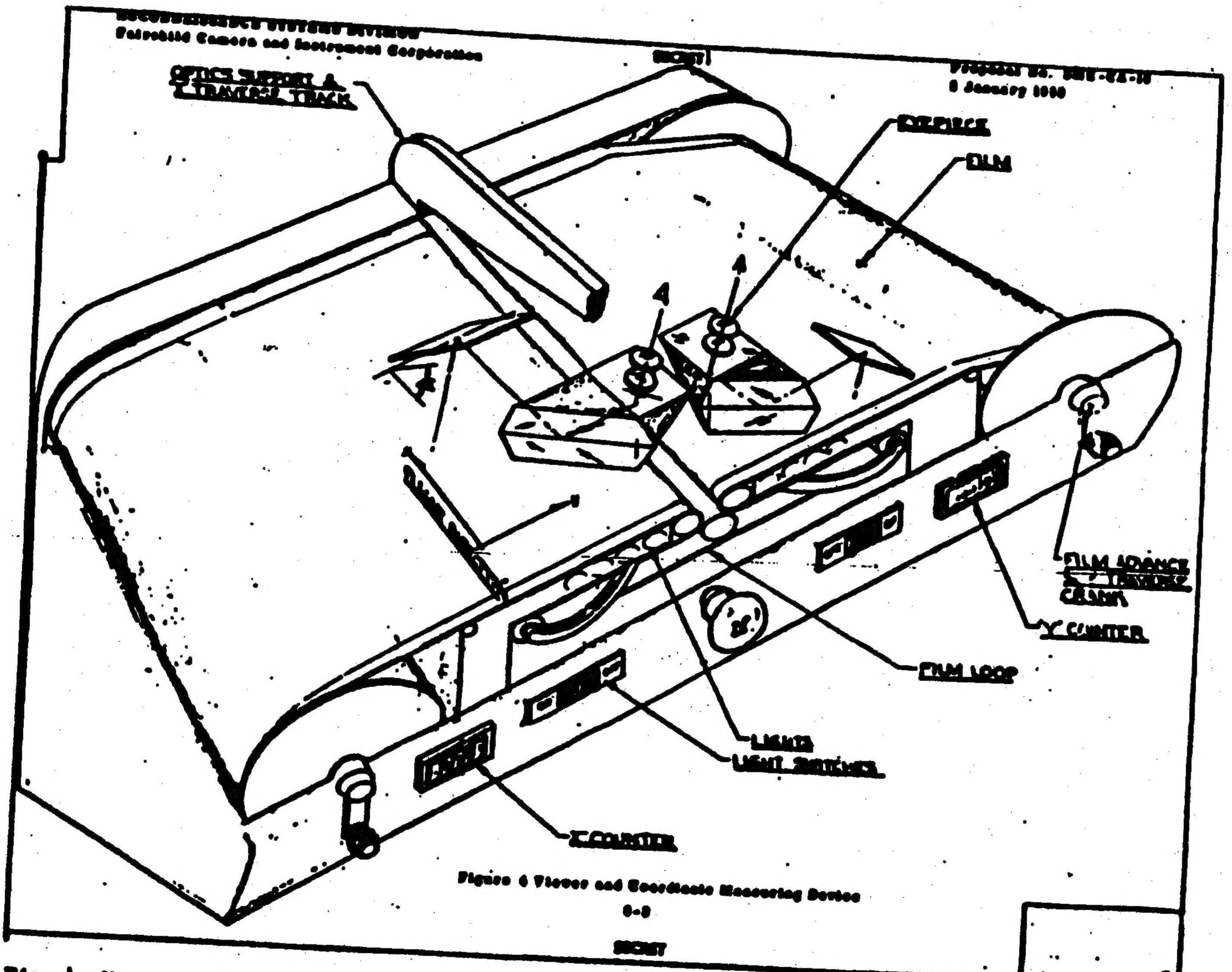
Fairchild Camera and Instrument Corporation
SECRET
OPTICS SUPPORT & Z TRAVERSE TRACK
EYEPIECE
FILM
4
4
FILM ADVANCE & Y TRAVERSE CRANK
Y COUNTER
FILM LOOP
LIGHTS
LIGHT SWITCHES
X COUNTER
Figure 6 Viewer and Coordinate Measuring Device
SECRET

Fig. 4 Viewer and Coordinate Measuring Device